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„Field choice and flock composition of Lesser White-fronted Geese (*Anser erythropus*) at a staging site in Middle Sweden“

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List of abbreviations

am	*ante meridiem*
BG	Barnacle Goose
CG	Canada Goose
cm	centimetre
CRS	Coordinate Reference System
et al.	*et alii* = and others
e.g.	*exempli gratia* = for example
fe	expected frequency
Fig.	Figure
fo	observed frequency
GG	Greylag Goose
GPS	Global Positioning System
ha	hectare
ID	Identification number
km	kilometre
LWfG	Lesser White-fronted Goose
pm	*post meridiem*
Tab.	Table

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Abstract

In conservation of animal species, knowledge of the habitat of the species is important as it provides all livelihoods. As important is knowing the behaviour and how it is linked to the species' fitness. This study aims to gain knowledge on the habitat of the globally threatened Lesser White-fronted Goose (*Anser erythropus,* hereafter LWfG) as well as on factors influencing the formation of interspecific flocks. Therefore, 102 fields at a stepover site in Hudiksvall, Sweden, were observed and categorised regarding their characteristics. Furthermore, the field use was examined in conjunction with GPS data of the years 2015 to 2021. In addition, data on the flock composition between LWfG, Greylag Geese (*Anser anser*), Canada Geese (*Branta canadensis*), and Barnacle Geese (*Branta leucopsis*), along with the behaviour were collected. This study determined specific fields in each year that were preferred by the LWfG. These were not consistent over several years. As possible factors influencing the field choice of the LWfG in this area a vegetation height of maximum 15 cm as well as vicinity to open water were detected in this study. In addition, indications of an influence of the flock composition on the field choice could be found as well. As LWfG showed less alert behaviour in mixed flocks, this indicated a formation of interspecific flocks to reduce their risk of predation. The found information on the habitat choice as well as on the interspecific relationships can help conservation programs to protect important habitats for the LWfG.

1. Introduction

1.1 Conservation

Conservation is defined by the World Conservation Strategy (1980) as “the management of human use of the biosphere” with the purpose to bring the present generations the greatest possible sustainable benefit. At the same time, this management ensures that this possibility also exists for future generations, adapted to their needs and wishes. Furthermore, this strategy declares sustainable use, restoration, preservation, and improvement of nature as components of conservation. Hambler and Canney (2013) attempted a new, more summed up definition, as they wrote: “conservation is the protection of wildlife from irreversible harm”. They thereby define wildlife as the sum of all non-domestic species and populations of animals, plants and microorganisms, as well as their habitats, while harm is defined as damage or decline due to human actions.

To answer the question why conservation is important, Hambler and Canney (2013) define two categories all arguments can be assigned to: Utilitarian and non-utilitarian. Utilitarian arguments argue with so called use-values nature has to offer, whereas non-utilitarian arguments utilize so called non-use values. Summarised, non-use values refer to the intrinsic and the existence value. Therefore it can be argued that every species has the right to live and as a consequence they need to be conserved (intrinsic value). The other argument in this category is, that people have a benefit only from knowing of the existence of a species or a habitat (existence value). As people can physically benefit from nature, arguments using these benefits are classified as use values. These have an economic character and are also called ecosystem services. Ecosystem services are the services an ecosystem provides to humans and that they benefit from (Daily, 1997). According to this, biodiversity should be conserved because human can benefit directly from it through food, fuel or medicine, but also through its aesthetics, ecotourism and genetic resources (Hambler & Canney, 2013).

Having answered the question why conservation is important, the question on what exactly should be conserved arises. The two definitions cited above give two different goods that should be protected: The biosphere and the wildlife. As the biosphere consists of all ecosystems on the world (Hutchinson, 1970). And as Hambler and Canney (2013) define their “wildlife” as “the sum of all non-domestic species and populations of animals, plants and microorganisms, and their habitats” which also concludes to all ecosystems, both definitions centre the same protected goods. Since ecosystems are constituted of species and their habitat, it is all in all the biodiversity that needs to be conserved. That means all species and habitats should exist in the future and therefore their extinction must be prevented. Consequently, there are priorities of what to conserve, according to their respective risk of extinction.

One prominent organisation to categorise species according to their risk of extinction is the International Union for Conservation of Nature (IUCN). They use five criteria to evaluate the status of a species' risk of extinction: The population size reduction (over ten years or three generations), the geographic range in the form of extent of occurrence and/or the area of occupancy, a small population size and decline, a very small or restricted population and a quantitative analysis that is indicating the probability of extinction in the wild (IUCN, 2012). The IUCN Red List also includes information about the species' habitat and the importance of each habitat to the species. Giving all this information, the IUCN Red List is a great tool to inform and plan actions for conservation.

Within the European Union (EU), the Habitats Directive ensures that each member state is monitoring the condition of its flora, fauna and habitats and obliges them to manage them into good conditions ("Council Directive 92 /43 / EEC on the conservation of natural habitats and of wild fauna and flora," 1992). Based on that directive and lists, actions for conservation can be planned.

1.2 Conservation strategies

To preserve species, there are in general two different strategies: *in-situ* and *ex-situ*. *In-situ* strategies take place in the natural habitat of the target species and provide therefore the best options for long-term conservation. In contrast, *ex-situ* strategies take place outside of the natural habitat of the target species (Mestanza-Ramón et al., 2020). They are used when *in-situ* strategies are not possible or supplement *in-situ* strategies when these are not sufficient to preserve the target species, e.g. if the natural habitat does not exist (in enough amount/good condition) anymore or the population size is too small to prevent inbreeding or inbreeding is already happening (Convention on Biological Diversity, 1992; IUCN/SSC, 2014). *Ex-situ* strategies pose rather short-term possibilities for conservation. Both strategies can get executed through various techniques. Common techniques for *in-situ* conservation are the monitoring and management of species or their habitat (IUCN/SSC, 2013).

One example of such habitat management in favour of a target species is the habitat restoration for the Piping Plover (*Charadrius melodus*) that took place in 2004 in New Jersey, USA. The habitat restoration contained specific features to make the habitat attractive for the Piping Plover, such as unvegetated nesting habitat, and artificial tidal ponds for foraging and plover walkover to allow the chicks to access the foraging pond (Smith et al., 2005 as cited in Maslo et al., 2012). An evaluation of these measures declared them as successful and highlighted the artificial ponds as effective part of the restauration (Maslo et al., 2012). Nonetheless, the evaluation also showed another big problem in conservation: The disturbances due to human actions. In the example of the Piping Plover, human disturbances led to lower feeding rates (Maslo et al., 2012).

In addition, the habitat sometimes can act as a trap for a species when the environment was altered in a short period of time by humans (Schlaepfer et al., 2002). This is a consequence of traits which have been indicating a beneficial habitat to a species, being now caused by human actions (Schlaepfer et al., 2002). Therefore, they are no longer linked with benefits, but rather lead to a lower reproductive success. Furthermore, management actions that are conducted to help the target species can turn out to work as such a trap as it was the case in Wood Ducks (*Aix sponsa*) in Illinois, USA (Semel & Sherman, 2001). Nest boxes were erected to increase the reproductive success of the Wood Ducks, but due to their mechanism of choosing nests, this management action led to higher interspecific parasitism and resulted in a decrease of reproductive success (Semel & Sherman, 2001). This is a good example, that not every technique in conservation is suitable for every species, while it highlights the importance of knowledge on a species' ecology.

Another possibility to provide safety to species is to put either the species or their habitat under protection by creating protected areas or by protecting the species from disturbances during sensitive periods, e.g. breeding or hibernation ("Council Directive 92 /43 / EEC on the conservation of natural habitats and of wild fauna and flora," 1992; Convention on Biological Diversity, 1992).

One big threat to conservation that often works against the aforementioned conservation actions is illegal hunting (Gavin et al., 2010; Heurich et al., 2018). This threat is difficult to control, as often the control would need a lot of humans, that are not available at the authorities in charge (Heurich et al., 2018; Zahler et al., 2004).

To conserve species outside their natural habitat (*ex-situ*), a technique is for example saving seeds or DNA in storages, like it is done at the National Department of Plant Genetic in Ecuador, where approximately 28,000 accessions of plant species are stored (Mestanza-Ramón et al., 2020). Another *ex-situ* technique is captive breeding for the reintroduction or reinforcement of wild populations as it was done with the Takhi (*Equus ferus przewalskii*). The Takhi went extinct in the wild in the 1960s and to reintroduce this species into its natural habitat the individuals present in zoos were bred and then coordinated by reintroduction programs they were reintroduced (Van Dierendonck & Wallis de Vries, 1996). As the population consisted of about 350 individuals in 2012, the Takhi has been down-listed by the IUCN to Endangered in 2011 (Walzer et al., 2012). Therefore, the reintroduction could be considered as successful. However, one of the factors leading to the extinction in the wild was pasture competition with livestock and the number of livestock is currently increasing at the area (Walzer et al., 2012). This does not only lead again to competition between livestock and the Takhi, but also allows parasites to spread from livestock to Takhi and lead to a high mortality in juveniles (Tarav et al., 2017). Furthermore, hybridisation of Takhi and nomad's horses are possible and therefore pose a threat to the conservation of this species (Tarav et al., 2017).

Another issue is the genetic uniformity since the whole population is based on 13 founder individuals (Walzer et al., 2012). A loss in genetic diversity means an elevated extinction risk (Frankham et al., 2002; Van Dierendonck & Wallis de Vries, 1996). Among these and other complications, the determination of suitable habitats for the reintroduction was also a difficulty (Van Dierendonck & Wallis de Vries, 1996).
The habitat of a species plays a central role in conservation as it provides all livelihoods, such as feeding-, mating- and breeding grounds to animal species or nutrients and conditions to meet the needs of reproduction and survival to plant species (Krausman & Morrison, 2016). All these are possibilities where *in-situ* management of the habitat can intervene and support, for example by setting up nest boxes or cutting vegetation that inhibit the presence of the target species (Bogyó & Tar, 2017; Bolton et al., 2004). The preservation of the species' natural habitat is crucial to long-term conservation. Only if the habitat exists in a sufficient way qualitatively and quantitatively the target species will be able to survive in it and species conserved *ex-situ*, for example by captive breeding, can be brought back into their habitat (Van Dierendonck & Wallis de Vries, 1996). Therefore, knowledge about the habitat of those species is of high importance.

One of those species, that is threatened by illegal hunting and habitat loss is the Lesser White-fronted Goose (*Anser erythropus*) (Jones, 2008; Markkola et al., 2003). As a consequence, it is in need of conservation actions The global population is listed by the IUCN as Threatened since 1988 and, as the categories changed, as Vulnerable since 1994 (IUCN, 2012, IUCN 2021). This listing did not change despite several conservation actions were conducted in different countries to protect this species (Bogyó & Tar, 2017; Projekt Fjällgås, 2014a).

1.3 Lesser White-fronted Goose (*Anser erythropus*)

The Lesser White-fronted Goose (*Anser erythropus*, hereafter LWfG) is a bird species belonging to the family *Anatidae* within the order of *Anseriformes* with no subspecies being recognised (Jones, 2008). It is considered the smallest goose in the genus *Anser* (Jones, 2008), with a size of 53 to 66 cm (Madge, 2010).

In LWfG both sexes look alike, with the males being a little bit larger (Madge, 2010). They are grey-brown with lighter breast and underparts, that are horizontally striped (Fox, 2005; BirdLife International, 2022; Madge, 2010). Most prominent are probably their name-giving white forehead that starts at the base of the bill and their bright, yellow eye-ring around their brown eyes (Beaman, 2007; Fox, 2005). The bill is small and pink with a nail pale, whereas the legs and feet are yellow-orange to orange in colour (Fox, 2005). LWfG look quite similar to the White-fronted Goose (*Anser albifrons*), but can be distinguished due to the LWfG being smaller, having a rounder head, as well as the bill being smaller, shorter and in a brighter pink (Beaman, 2007). Furthermore, the prominent white forehead is more extant in the LWfG, the belly-bars are more restricted in LWfG and the bright yellow eye-ring is in most cases missing in *A. albifrons* (Beaman, 2007; Fox, 2005).

They are long-distance Palearctic migrants, with their breeding grounds being in the sub-arctic zone from northern Fennoscandia to eastern Siberia (Jones, 2008). In late August to early September this species departs from their breeding grounds, migrating to their staging sites and moving from there on to their wintering sites (BirdLife International, 2022). Their staging and wintering sites, as well as their migration routes, are only partially known and differ between the subpopulations (BirdLife International, 2022; Jones, 2008).

There are four subpopulations that can be distinguished. Three of them are “surviving components of the species’ formerly more extensive breeding range”, while the fourth is a in the Netherlands wintering population originating from a reinforced breeding population in Sweden (BirdLife International, 2022; Jones, 2008). The three subpopulations considered as surviving components are the Fennoscandian, the Western Asia main and the Eastern Asia main subpopulation (BirdLife International, 2022; Jones, 2008). An overview of their distribution can be seen in Figure 1.

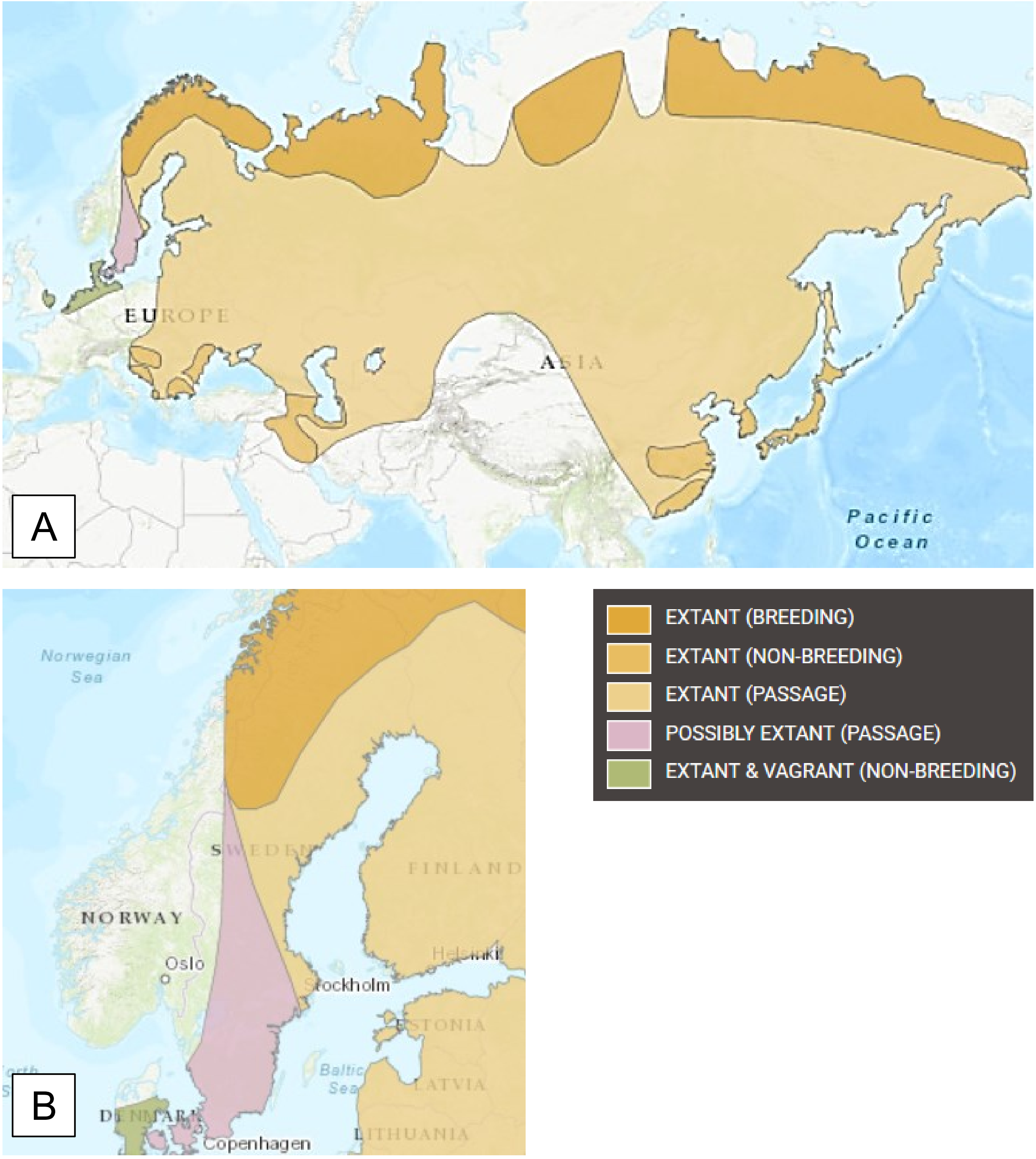

Figure 1. *Distribution of the Lesser White-fronted Goose*
A: Global distribution of the Lesser White-fronted Goose. B: Distribution of the Lesser White-fronted Goose in Sweden (BirdLife International and Handbook of the Birds of the World (2016) 2014. Anser erythropus. The IUCN Red List of Threatened Species. Version 2021-3)

The habitat requirements of the LWfG differ between their breeding grounds and their staging and wintering sites. For breeding, LWfG use sub-arctic tundra and forest tundra, preferably bush tundra interspersed with lakes and bogs (Jones, 2008). The habitats differ between the different locations within their breeding range (Jones, 2008). In Sibiria for example, they built their nests amongst grass or dwarf shrub heath on snow free patches (Fox, 2005). They do not breed in colonies, but in monogamous pairs in isolated territories (Johnsgard 1978, as cited in BirdLife International, 2022; Madge, 2010). These pairs seem to last lifelong and their clutch size is between four and six eggs (Fox, 2005; Johnsgard 1978, as cited in BirdLife International, 2022). For staging and wintering they use wetlands, especially freshwater or brackish lakes, as well as marshes, semi-natural grasslands and cultivated land (Jones, 2008). The proximity to water is important to LWfG, as lakes serve the geese as roosting place (Tar, 2003). Also, large fields that allow a view far away are mentioned to be important for LWfG (Markkola et al., 2003; Tar, 2003). All of these types of habitats are threatened through extensive land-use and the changes the climate change is resulting in (Jones, 2008).

The LWfG is solely herbivorous with their diet changing according to the regional flora and what matches their requirements, as well as the season (Cong et al., 2012; Fox, 2005; Markkola et al., 2003). The composition of their diet is similar at the staging and wintering sites, as it consists mainly of monocotyledons of the order of Poales (Cong et al., 2012; Karmiris et al., 2014; Markkola et al., 2003; Tar, 2003). Furthermore, a preference for fresh, newly grown leaves is found (Cong et al., 2012; Tar, 2003). Not many studies investigated the diet at the breeding grounds, but two fen plant species were identified to correlate with the occurrence of LWfG (Friberg, 1997 as cited in Markkola, 2022). Both of them are monocotyledons, one also of the order poales (as at the staging and wintering grounds) the other one belonging to the order Alismatales (Friberg, 1997 as cited in Markkola, 2022). As most geese species, the LWfG forages in flocks, single-species as well as interspecific flocks (Markkola, 2022; Tar, 2003). Furthermore, they were observed to feed on fields vertebrate herbivores were grazing on, since this provided short grass and prevented the scrub encroachment of these fields (Lorentsen et al., 1999 as cited in Markkola et al., 2003; Tar, 2003). Although the species the LWfG fed on differed between the different habitats, there is an analogy of feeding on short grasses in close proximity to water. Possible reasons for this could be the small size of their bill and their need for high-quality food (Durant et al., 2004; Heuermann et al., 2011).

The LWfG is listed as Vulnerable by the IUCN in Europe as well as globally (IUCN 2021). This is justified by the species' rapid decline of the breeding population in its key breeding area in Russia and the fact that a continuous decline is to be expected due to ongoing hunting and an ongoing loss of their habitat (BirdLife International, 2022, IUCN 2021). In Europe, the categorisation is justified due to the European breeding population meeting the criterion of a very small population with approximately 170-270 pairs being present after undergoing several decreases (IUCN 2021). In the regional assessment of the European Union, the LWfG is categorised Critically Endangered due to their extremely small population size (IUCN, 2021). The main threats to LWfG are illegal hunting and habitat loss (in order of importance). These apply mainly on adult birds on their staging and wintering sites, as well as on their flyways (Projekt Fjällgås, 2014a; Jones, 2008)

1.4 Aim of the study

International efforts for the conservation of the LWfG are taken. There is the international action plan for the Western Palearctic population of the LWfG, containing the Fennoscandian, Western Asia main and reinforced subpopulation (Jones, 2008). This action plan analyses threats and measurements taken while formulating goals and knowledge gaps that need to be filled. In order to meet these goals and fill these gaps each country, that is contributing to this action plan, takes actions. In Hungary for example, habitat that serves as staging site was restored in favour of the needs of the LWfG (Bogyó & Tar, 2017). The Projekt Fjällgås in Sweden has the goal to conserve this species via reinforcement with captive-bred LWfG (Projekt Fjällgås, 2014a). Furthermore, a lot of studies have been executed to investigate specific habitats of the LWfG, for example in Greece, Finland, and Hungary in order to fill gaps of knowledge (Karmiris et al., 2014; Markkola et al., 2003; Tar, 2003). Since such information is missing for the Swedish population, this study aims to fill this gap. Based on the findings at other staging sites, I hypothesise LWfG showing a preference for specific fields at their staging site in Hudiksvall. Therefore, I predict that specific fields will be used more often than others and that these fields show an analogy in at least one characteristic, e.g. the growth height or the agricultural use.

Furthermore, this study focuses on the factors influencing the formation of interspecific flocks with other goose species in this area. Since LWfG are pray to several species abundant in Sweden such as Goshawk (*Accipiter gentilis*), Golden Eagle (*Aquila chrysaetos*) and White-tailed Sea-eagle (*Haliaeetus albicilla*), they need to be able to detect predators early (Jones, 2008). The formation of flocks is one possibility to detect predators earlier and also lowers the individual risk of predation due to the dilution effect (Kappeler, 2012). As the population size of the LWfG is small the mixing with other species could be an opportunity to build larger groups. Furthermore, Székely et al. (1989) could show in a field experiment on tits that in presence of a predator formation of larger interspecific foraging-flocks occurred. Therefore, I hypothesise that interspecific flocks are formed by the LWfG in order to decrease their risk of predation. Due to the dilution effect, I predict that groups of LWfG that contain fewer individuals are rather observed in a mixed flock with other goose species. Another benefit of groups that lowers the risk of predation is the shared alertness. I therefore predict less LWfG showing alert behaviour in mixed flocks, as well as I predict less LWfG showing alert behaviour the larger the flock is.

The results of this study could contribute to long-term protection of important foraging sites of the LWfG in Hudiksvall. Moreover, gained knowledge on why interspecific flocks are formed could help planning management actions to prevent hunting incidents in the future, as forming interspecific flocks with other goose species, especially quarry species, could bring LWfG into greater risk of being accidentally shot.

2. Material and methods

2.1 Study animals

The LWfG observed for this study belonged to the subpopulation wintering in the Netherlands based on the staging site they were observed in (Jones, 2008). This population comprises approximately 20 breeding pairs (National Summary Sweden, 2020) and goes back to a captive-breeding programme in Sweden performed by the Swedish Sportsmen's Association that took place between 1979 and 1999 (Liljebäck et al., 2021; von Essen, 1991). The LWfG had been a common bird to breed in Sweden until the early 20th century (Projekt Fjällgås, 2014a). After a few decades of decrease (Norderhaug and Norderhaug, 1984 as cited in van Essen, 1991) the breeding population in 1978 was estimated at around ten breeding pairs (Nordic Council, 1978 as cited in von Essen, 1991). This is why this programme to reinforce the Swedish population of LWfG was started (von Essen, 1991). Its breeding stock was built up with birds and eggs gained from waterfowl collections in the UK and continental Europe (Jones, 2008). Barnacle Geese (*Branta leucopsis*), that were introduced to the Stokholm Zoo before, were used in this programme as foster parents (von Essen, 1991): The incubated eggs were given to the foster parents after 3 weeks and before the goslings were fledged, they were released with their foster parents within the former native range of the species in Swedish Lapland (Marchant & Musgrove, 2011; von Essen, 1991). Between 1981 and 1999 a total of 348 of these captive-bred LWfG were released in Swedish Lapland (Jones, 2008).

Since young geese learn the migration flyways from their parents at the first migration, the reintroduced LWfG use the flyway of their Barnacle Goose foster parents (Jones, 2008; Scott 1972 as cited in Sladen et al., 2002). This led to a completely different flyway of this subpopulation compared to this of the Fennoscandian subpopulation (Jones, 2008). The Swedish LWfG breed in Swedish Lapland have their staging sites on the east coast of middle Sweden and winter in the Netherlands (Jones, 2008). The produced changed flyway was intentional. In fact it was the reason the Swedish Sportsmen's Association decided to use Barnacle Geese as foster parents: As hunting on the migration flyways is presumed to be the biggest threat to the LWfG, a changed flyway was thought to protect the LWfG from this threat (Projekt Fjällgås, 2014a). This seems to work out as the Swedish population of LWfG is the only one that has not been decreasing in the last decade, but also increased slowly despite the stop of reinforcing the population with captive-bred individuals (1990: about 10 breeding pairs, 2004: about 13 breeding pairs, 2011: 15 to 20 breeding pairs) (Projekt Fjällgås, 2014b). The programme stopped in 1999 due to the discovery of Greater White-fronted Geese (*Anser albifrons*) genes in some of the captive breeding population (Projekt Fjällgås, 2014a). This was in conflict with conservation as hybridisation is a threat to threatened species as it can lead to extinction through outbreeding depression (Todesco et al., 2016).

The Projekt Fjällgås restarted the captive breeding programme with a new breeding population in 2005 and has been releasing individuals again since 2010 (Projekt Fjällgås, 2014b). This time no foster parents are used, as the wild conspecifics in Sweden already use the changed flyway and the released individuals are following them (Projekt Fjällgås, 2014d). For the release, the captive-bred goslings are transported to the breeding area in Northern Sweden, where release pens are erected at places near wild breeding pairs with goslings (Projekt Fjällgås, 2014d). After a from afar supervised habituation phase of at least 24 hours, the captive bred goslings are released out of the release pen into the wild (Projekt Fjällgås, 2014d). Despite all this, the LWfG is still categorised as Critically Endangered by the Swedish Redlist (SLU Artdatabanken, 2020a).

Next to the LWfG, this study observed Greylag geese (*Anser anser*, hereafter GG), Canada geese (*Branta canadensis*, hereafter CG) and Barnacle geese (*Branta leucopsis*, hereafter BG) as well. This was done to investigate mixed flocks of the LWfG with one of these species. The population size of each species in Sweden is quite different. According to the National Summary Sweden (2020), the population of GG in Sweden about 41000 pairs, 13000 pairs of CG, and 2900 pairs of BG.

2.2 Study site

The data were collected on fields around Hudiksvall (61°44'N, 17°07'E), a city of Gävleborg County, on the Swedish eastern coast of the Gulf of Bothnia, inside the bay Hudiksvallsfjärden. Hudiksvall lays on the migration flyway of the subpopulation wintering in the Netherlands. It serves as a staging site on this subpopulation's migration from the breeding grounds in Swedish Lapland to their wintering sites as well as on their spring migration back to the breeding grounds. Hudiksvall thereby is one of the two most used staging sites in Sweden (Projekt Fjällgås, 2014c).

The city is bounded on the south-east by the bay. At the centre of Hudiksvall there is the lake Lillfjärden and north-west up country there are plenty of fields. The Lillfjärden is used around noon by different waterbird species as roosting site. Some of these are Greylag goose (*Anser anser*, hereafter GG), Canada goose (*Branta canadensis*, hereafter CG) and Barnacle goose (*Branta leucopsis*, hereafter BG), along with LWfG. Before and after roosting on the lake, these species are feeding on the fields around Hudiksvall.

The study fields were chosen prior to the field work. Therefore, GPS data of GG, BG and LWfG were analysed. The fields that were used by LWfG, GG and BG were marked in Google Earth (7.1.8.3036-version). This was to use the resulting map for navigation during field work (Fig. 2). In total, 102 study fields were selected, laying in an approximately 1540 ha sized area around Hudiksvall, with the fields having a mean surface area of 4.02 ha (± 0.31).

2.3 Data collection

2.3.1 Field observations

The data collection was introduced by an orientation phase of six days at the study site (30.07. to 04.08.21) with the aim to detect additional study fields, solve logistical issues, and gain preliminary information on the field's characteristics. Therefore, the fields lying next to the beforehand selected fields were also visited and checked for the occurrence of LWfG, GG, CG or BG. Since these are the most common goose species in this area, interspecific flocks with the LWfG were expected and therefore GG, CG and BG were observed as well. If one of the species occurred more than once, the respecting field was added to the map of the study fields. In addition, fields that were not study fields, but at least one of the goose species occurred more than once on them during the data collection, were added to the study fields until the 10th day of data collection. Finally, a total of 102 fields were chosen as study fields.
Furthermore, the orientation phase was also used to choose the best spots for the observation for each field, as due to the hilly landscape, trees, buildings or hay bales, the whole field was not always visible from every spot. Moreover, the reaction of the geese to the approach of the observer was documented in order to determine a time span for a habituation phase. The time span of five minutes was chosen based on these observations as after this time the number of geese showing alert behaviour as a reaction to the approach reduced.
In addition, the fields were categorised regarding their characteristics in this phase. The first characteristic was the agricultural use, where five categories were defined: harrowed, stubble field, crop, meadow and pasture area (Tab. 1).
The other characteristics of the fields referred to their surrounding and contained information about water, roads or buildings in direct neighbourhood to the field and if so, of which kind they were (Tab. 1). In addition, information on trees in the direct neighbourhood were collected. Due to characteristic of the mean growth height being able to change throughout the study period, it was not determined in the orientation phase, but noted down for each observation.

Table 1. *Overview of the characteristics of the fields taken into account in this study.*

Characteristic	Category	Description
agricultural use	harrowed	fields that (upper layer) consisted only of (loose) soil
	stubble field	fields where crop grew on and got cut, so only the lower part of the crop-stems was still on the field
	crop	fields with any sort of crop growing on
	pasture area	fields that were used as pasture area, indicated by livestock on the field and/or livestock fences around it
	meadow	all other fields with vegetation on them
surrounding	water	water (e.g. ditch) in direct neighbourhood to the field
	road	road in direct neighbourhood to the field
	building	a barn, farm or house in direct neighbourhood to the field
	tree	tree(s) in direct neighbourhood to the field; the formation of the tree(s) was categorised as single, linear or grouped; the position of the tree(s) was categorised as edge or centre
mean growth height	0	the mean growth height of the field was 0 cm
	<10	the mean growth height of the field was <10 cm
	10-15	the mean growth height of the field was 10-15 cm
	15-30	the mean growth height of the field was 15-30 cm
	30-50	the mean growth height of the field was 30-50 cm

During the data collection period (05.08. to 24.08.21; 20 days), the fields were observed four times a day, with at least one hour between two observations of the same field. Each field was observed 60 times. In order to randomise the order of fields for each observation round, the fields were grouped on the basis of their geographical position with approximately the same number of fields in each group (green: 23, yellow: 23, red: 26, blue: 30) (Fig. 2). Each observation round contained all 102 fields and measured approximately 50 km.

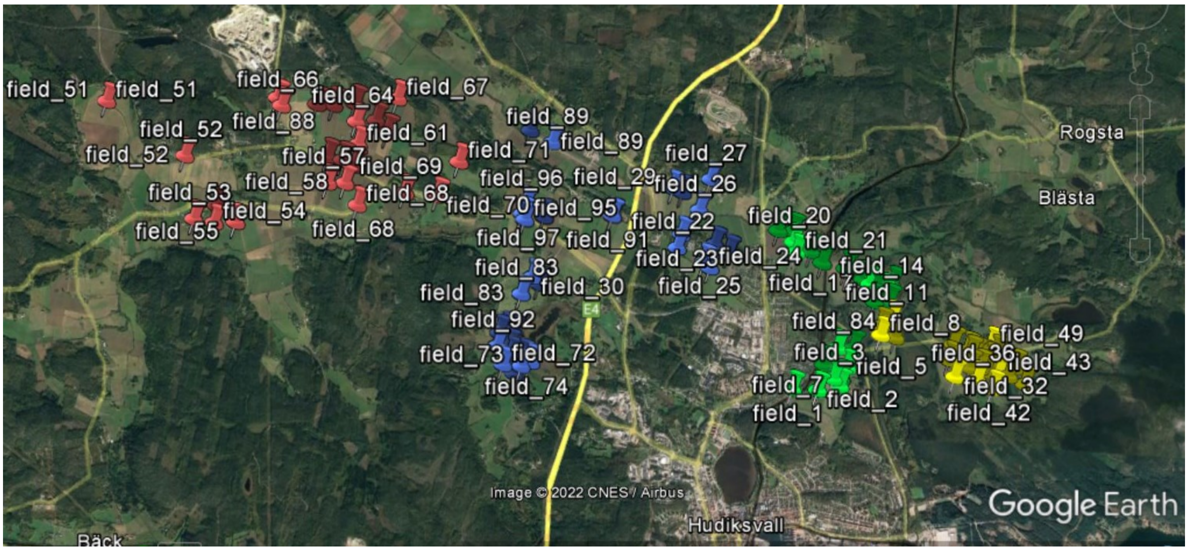

Figure 2. *Map of all study fields.*
Each map pin marks one study field with its field_ID. The different colours refer to the respective group. (Google Earth, 7.1.8.3036-version)

The first round of observations started at 6 am and after all fields were observed, the second round followed, lasting until the last observation of the second round was done (approximately 12:45 am): The third round started at 2 pm, followed by the fourth round that stopped after the last observation of the fourth round was done (approximately 07:30 pm).
Due to bad weather conditions, changes in the organisation of the rounds were necessary on two days of data collection. The start of the first observation round was postponed until the fog cleared up at the 09.08.21 and at the 12.08.21 there was a break in the third observation round until the thunderstorm was over. In both cases, the order of groups was retained.

Starting with the observation, the following variables were collected and noted onto the data sheet: present species, number of individuals and behaviour. The date and the time of the day were noted as well as the mean growth height of the field (Tab. 1). The number of individuals was noted per species. It was counted for groups up to 15 individuals. For more than 15 individuals being present the number was estimated by dividing the group of individuals of one species visually into numeric groups of ten individuals and then counting these groups. The behaviour was also noted per species. It was differentiated between the following four types of behaviour: Resting, feeding, preening, and alert (Tab. A1). These were defined after Boz et al. (2021), Drent and Swierstra (1977), and Fox and Madsen (1981). The behaviour was sampled using scan sampling each species. The group was scanned and the number of individuals performing the different types of behaviour was counted or estimated in percent for groups larger than 50 and noted down. Afterwards, the percentage of the shown behaviour per species was calculated.

The observations were done using a Swarovski spotting scope (magnification: 30x to 70x) and noted down by pen and paper. The fields were approached by car. When geese were visible on the respective field, they were given five minutes of habituation before the data collection started. This was done to prevent the occurrence of the observer from influencing the performed behaviour. During this habituation phase the “mean growth height” was already estimated by eye and noted down.
In total, 819 observations were performed.

2.3.2 GPS data

The GPS data of the years 2015 to 2021 (LWfG), 2017 to 2021 (Greylag Goose *Anser anser*) and 2018 to 2021 (Barnacle Goose *Branta leucopsis*) were provided by Helmut Kruckenberg from the Institute für Wetlands and Waterbird Research e.V..
LWfG were tagged with GPS loggers in 2014 (8 individuals), 2015 (4 individuals), 2016 (7 individuals), 2017 (1 individual) and 2018 (3 individuals). This was done at three different locations in Seden: at the lake Lilfjärden in Hudiksvall, at the Pieljekaise national park and at the Nordens Ark. The GPS loggers sent their location in intervals from 15 minutes to three hours and stayed on the individuals for a few months up to five years.
Eight individuals of Greylag Geese were tagged in 2017 at three different locations: The lake Lilfjärden in Hudiksvall (5 individuals), Sweden, Öster Malma (2 individuals), Sweden and Schlüttsiel (1 individual), Germany. In 2018 eleven individuals were tagged at Öster Malma (2 individuals), Sweden and the lake Lilfjärden in Hudiksvall (9 individuals). The loggers sent their data for different time periods: Some just for a few months, others five years and still sending today. 12 of them sent their position every 15 minutes, while seven of them sent it every 30 minutes.
The Barnacle Geese were tagged at the lake Lillfjärden in Hudiksvall, Sweden. In 2018, three individuals were tagged and another individual was tagged in 2021. The loggers are sending their position every 15 minutes. One logger stopped sending its location in 2018, all others are continuing to send their location up until this day.

2.4 Data Analyses

2.4.1 Field choice

To test which fields were preferred by the LWfG, a Pearson's χ-squared test was performed. Therefore, the observed frequency (fo), meaning the number of sightings of LWfG on each field, was compared to the expected frequency (fe), that was calculated the following way:

$$fe = \frac{\text{Number of all sightings of LWfG}}{\text{Number of fields used by LWfG}}.$$

The χ^2 value is calculated the following way:

$$x^2 = \sum_{i=1}^{n} \frac{(fo - fe)^2}{fe},$$

with n being the number of fields used by LWfG. The calculated χ^2 value then gets compared to the respective critical value according to the right degree of freedom (n-1) and the desired significance level, in this case 95 %. The critical values can be found in the "Upper-tail critical values of χ^2 distribution"-table. The Null hypothesis of this test is that the observed frequency is consistent with the expected frequency. This is to be rejected if the calculated chi-squared value is higher than the critical value. The fields that were used more often than expected were considered as preferred.

The fields that were found to be preferred then got analysed and compared regarding their characteristics. This was done in order to find a homology in one or more characteristics of the fields that therefore seem to be important for the LWfG. To compare the field choice of the LWfG with the other species, preferred fields were calculated as described above for the other species as well.

To investigate the consistency of the field choice and the overlap of the field choice between species, the available GPS data were analysed (

. Therefore, the GPS data were downloaded as ESRI shape file from movebank.org and imported as point vector data into QGIS (version 3.24.0). To be able to compare the results gained through the GPS data with the data gained during the field work observations, only the time span around the migration in autumn was analysed. Therefore, the data were downloaded filtered by date with the timespan being set to 01.07 to 31.10. of each year, based on the literature on LWfG migration plus a month before and after to make sure to not miss any data of the autumn migration (BirdLife International, 2022).

***Table 2**. Overview of tagged individuals per species and year.*

	LWfG	BG	GG
2015	6	-	-
2016	11	-	-
2017	4	-	9
2018	5	3	17
2019	1	2	14
2020	-	2	9
2021	1	3	8

As fundamental map a map from Google Maps was added as a XYZ tile. Based on this map, a vector layer was added to each project containing all study fields as polygons. Fields in the study area that were used by the species but were not included in the study fields of the field work were created as polygons in another vector layer. This vector layer included 482 additional fields and was added to each project as well. As a result, each project had a XYZ tile containing the fundamental map, two vector layers containing field polygons and one to three vector layers containing point data of the GPS data available. All layers in each project were in the coordinate reference system (CRS) EPSG:3857 (WGS 84 / Pseudo-Mercator). Using the vector analysis-function "Count points in polygon" the usage of each field was determined for each year regarding the species and the migration. The count data was extracted from the attribute table into an excel file. This way a total of 584 fields were investigated. The count data of points in polygon were transferred into an excel file and the preferred fields per year and species were calculated as described afore. The overlap of the preferred fields between the years as well as between the species was calculated in percent using the following formula:

$$\frac{\text{Number of preferred fields}_{(\text{species a})}\ \text{overlapped between years/species}}{\text{total number of preferred fields}_{(\text{species a})}}$$

2.4.2 Flock composition

A flock was defined in this study as the entirety of individuals belonging to one of the four goose species observed in this study that are on the same field at the same time. The flock composition was noted down for each species. To analyse the flock composition, the flock size was calculated first by adding the numbers of individuals of all species being present on the same field for each observation. That given, the contribution of each species to the flock was calculated in percentage and according to Zhao et al. (2015) a cut-off threshold of 95 % was set to define mixed and unmixed flocks. So, species contributing < 95 % to the flock were defined as mixed, while species contributing ≥ 95 % to a flock and therefore being the majority of the flock were considered unmixed. This way, an observation of the same flock could lead to an "unmixed" for one species, while leading to a "mixed" for another species of the same flock. This was done because an effect of the minority species (≤ 5 %) on the majority species (≥ 95 %) seemed very unlikely, whereas vice versa an effect is very probable (Zhao et al., 2015). In total, 90 mixed and 3 unmixed flocks of LWfG were observed. For the GG 156 observations of mixed flocks and 115 of unmixed were done, while for the BG 135 mixed and 77 unmixed flocks were observed. The CG were observed 157 times in a mixed flock and 86 times in an unmixed.

3. Results

A total of 819 observations were done, with most of them containing Greylag Geese (N = 271), while LWfG were the less often observed species (N = 93) (Tab. 3). The LWfG was the species with the lowest numbers of individuals: On average five individuals of LWfG were present in an observation of this species, while the maximum number of individuals in an observation was 42 (Tab. 3).

Table 3. *Overview of observations per species. For the median and maximum number of individuals only observations were considered where the respective species were present.*

	number of observations	median of number of individuals per observation	maximum number of individuals
LWfG	93	5	42
BG	212	22	230
GG	271	40	630
CG	243	17	430
total	819		

3.1 Field choice

The χ^2 test revealed that the LWfG did not randomly choose the field they are using to feed on (χ^2= 87.79, $\chi^2_{(0.05)}$ = 33.92 / $\chi^2_{(0.005)}$ = 42.80, df = 22), but rather preferred specific fields. There were six fields LWfG were observed more often than expected by chance, which were therefore considered as preferred (Tab. 4). Comparing these fields' characteristics, one can see that all of them had a mean growth height below 15 cm, while they all were neighbouring roads and trees at the edge. Concerning the geographical position, it becomes apparent that all six preferred fields laid in a radius of 625 m to each other (Fig. 3). Furthermore, they all were in short (max. 500 m) distance to an approximately 7.58 ha sized lake.

Table 4. *Fields preferred (fo > fe) by the LWfG with their characteristics. (χ^2 = 65.37, $\chi^2_{(0.05)}$ = 11.07 / $\chi^2_{(0.005)}$ = 16.75, df = 5); fo meaning the observed frequency, fe meaning the expected frequency (4.04), N(sightings) = 93*

field_ID	fo	agricultural use	mean growth height [cm]	surrounding
field_75	17	stubble field	10 - 15	road, trees (edge)
field_100	12	harrowed	0	ditch, road, house, trees (edge)
field_93	9	pasture area	< 10	ditch, road, trees (edge)
field_30	8	meadow	10 - 15	road, barns, trees (centre & edge)
field_72	5	meadow	10 - 15	ditch, road, trees (centre & edge)
field_83	5	meadow	< 10, 10 - 15	road, trees (edge)

Figure 3. *Map (aerial shot) of the by LWfG preferred fields (highlighted in green).*

Comparing the preferred fields of each species calculated from the field observations with each other, it appears that the field preference did overlap between the species. All of the fields preferred by the LWfG were also preferred by GG. Four of six were also preferred by CG and three of them were preferred by the BG as well (Tab. 5).

Table 5. *Preferred fields per species based on the field observations. In order of priority from top to bottom.*

LWfG	BG	GG	CG
75	76	93	75
100	93	75	6
93	48	100	43
30	75	30	34
72	43	72	72
83	6	31	48
	30	83	93
	36	6	102
	35	92	30
	47	74	74
		99	
		69	
		34	

Based on the GPS data and the field observations, the LWfG had in each year (except 2021 GPS data) the highest overlap in its preferred fields with the GG (Tab. 6). The overlap thereby ranged between 40 and 100 %. The overlap with the BG was only in 2021 high (50-60 %). For the CG there was no data to compare between the years, but the data of the observations in 2021 showed an overlap of 67 % (Tab. 6).

Table 6*. Overlap in percent between the preferred fields of each species per year (row) and the other species in the same year (column). *data of the field observations*

		LWfG	BG	GG	CG
LWfG	**2017**	1	-	0.5	-
	2018	1	0.02	0.69	-
	2019	1	0	0.4	-
	2021	1	0.6	0.57	-
	2021*	1	0.5	1	0.67
BG	**2018**	0.05	1	0.6	-
	2019	0	1	0.04	-
	2020	-	1	0.46	-
	2021	0.36	1	0.55	-
	2021*	0.3	1	0.4	0.6
GG	**2017**	0.05	-	1	-
	2018	0.11	0.25	1	-
	2019	0.08	0.12	1	-
	2020	-	0.17	1	-
	2021	0.31	0.5	1	-
	2021*	0.46	0.3	1	0.54
CG	**2021***	0.4	0.6	0.7	1

The field choice was not consistent over several years. No field was preferred by the LWfG throughout all six years. Furthermore, only 3 % of the fields were preferred by the LWfG in five years, while 3 % were preferred in three years (Table 7). The majority of the fields were preferred only for one year, with this being the case for each species.

Table 7. *Percentage of fields preferred one, two, three, four, five or six years by each species. Based on GPS data.*

	one year	2 years	3 years	4 years	5 years	6 years
LWfG	0.74	0.19	0.03	0.00	0.03	0.00
BG	0.61	0.27	0.10	0.02	-	-
GG	0.46	0.24	0.18	0.10	0.03	-

3.2 Flock composition

Observations of the LWfG in unmixed flocks happened only in three out of 90 observations, therefore these results were not significant. Nonetheless, they indicated that LWfG only stay unmixed when they are high in numbers of individuals, as all of the observations of unmixed flocks contained more individuals, as indicated by the median (Table 3) of all observations (Fig. 4).

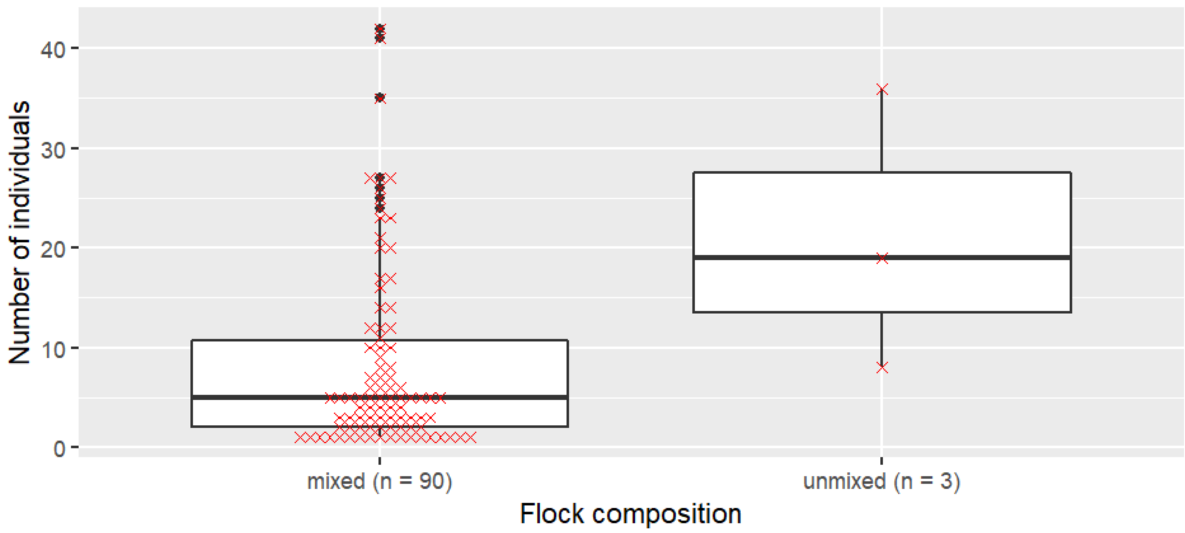

Figure 4. *Boxplot of the number of individuals of LWfG in the two flock composition categories.*

The percentage of individuals of LWfG showing alert behaviour showed no clear indication to be dependent from the flock size, as the proportion of LWfG showing alert behaviour was always low and most often even zero (Fig. 5). However, the high percentages occurred mainly in smaller flocks. In addition, the flock size was generally larger in mixed flocks.

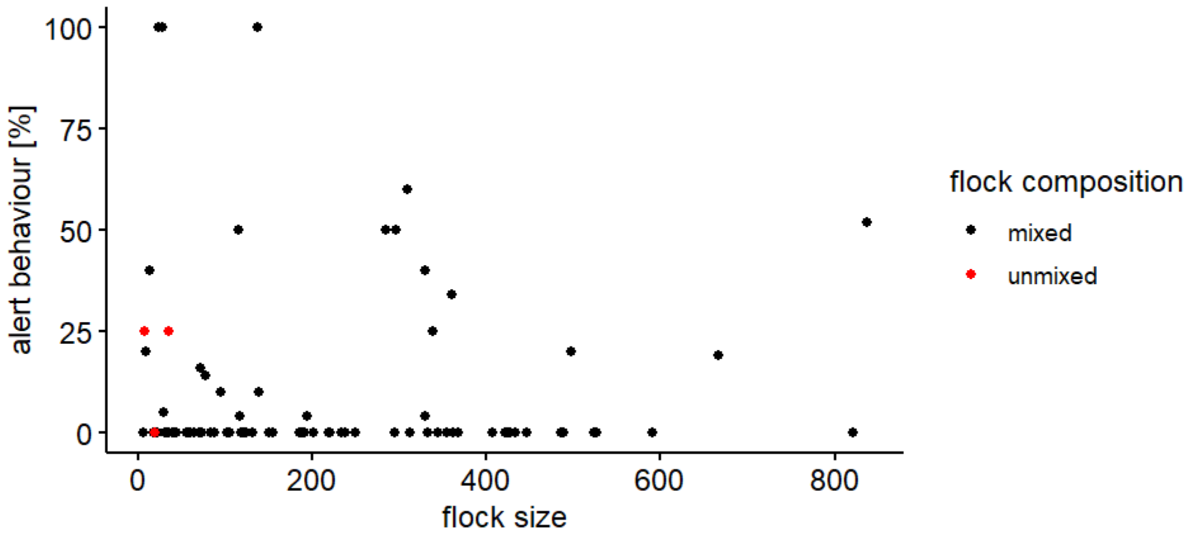

Figure 5. *Occurrence of alert behaviour in LWfG depending on the flock size.*

Furthermore, the behaviour of the LWfG differed between the two flock compositions (Fig. 6). In mixed flocks only around 50 % of the LWfG were feeding, whereas in unmixed flocks approximately 73 % were feeding. Alert behaviour was also shown by more geese in the unmixed flocks as in the mixed flocks (unmixed: ~17 %, mixed: ~9 %). However, more geese were resting in mixed flocks than in unmixed flocks (unmixed: ~8 %, mixed: ~24 %). This was also the case for preening (unmixed: ~3 %, mixed: ~15 %). To sum it up in mixed flocks there was less feeding and alert behaviour and more resting and preening in comparison with the unmixed flocks.

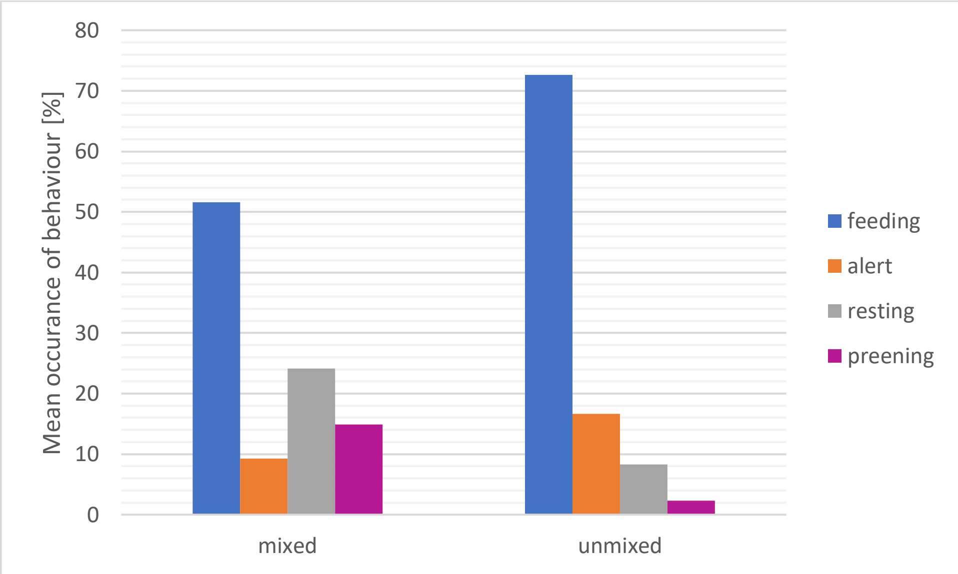

Figure 6. *Bar plots of the percentage of LWfG individuals showing each behaviour. Compared between mixed and unmixed flocks.*

The LWfG used pasture area only when they were in an unmixed flock, whereas in mixed flocks they used all of the agricultural use categories except crop (Fig. 7). Furthermore, pasture area was the second least category used in mixed flocks. In addition, none of the three fields used by unmixed LWfG was one of the fields considered as "preferred".

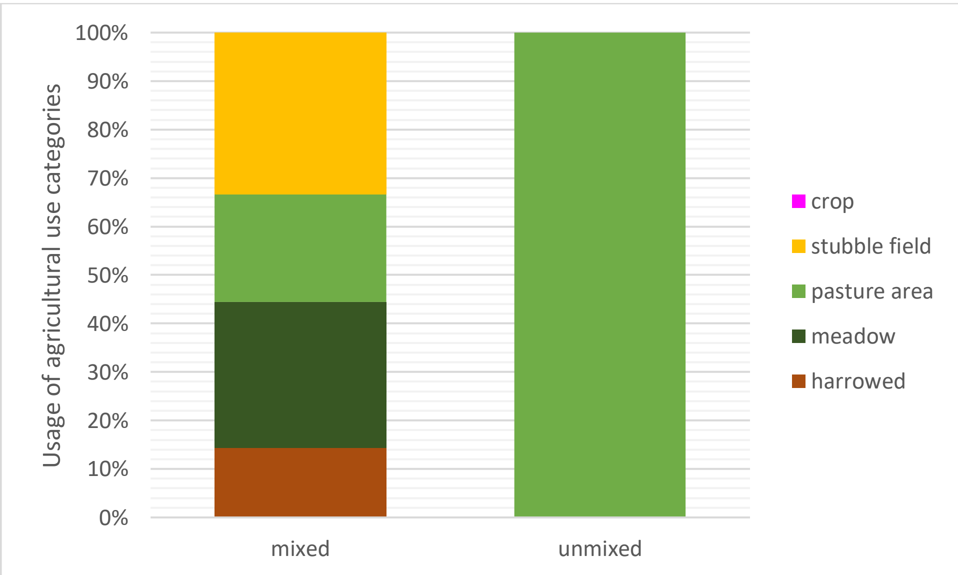

Figure 7. *Percent stacked bar plots of the usage of the different agricultural use categories by LWfG. Comparison between mixed and unmixed flocks.*

Comparing the usage of different growth heights within the two flock compositions, the majority of observations in mixed flocks was on fields with a mean growth height of 10 to 15 cm. The unmixed flocks of LWfG on the other hand were exclusively seen on fields with a mean growth height of 10 to 15 cm (Fig. 8).

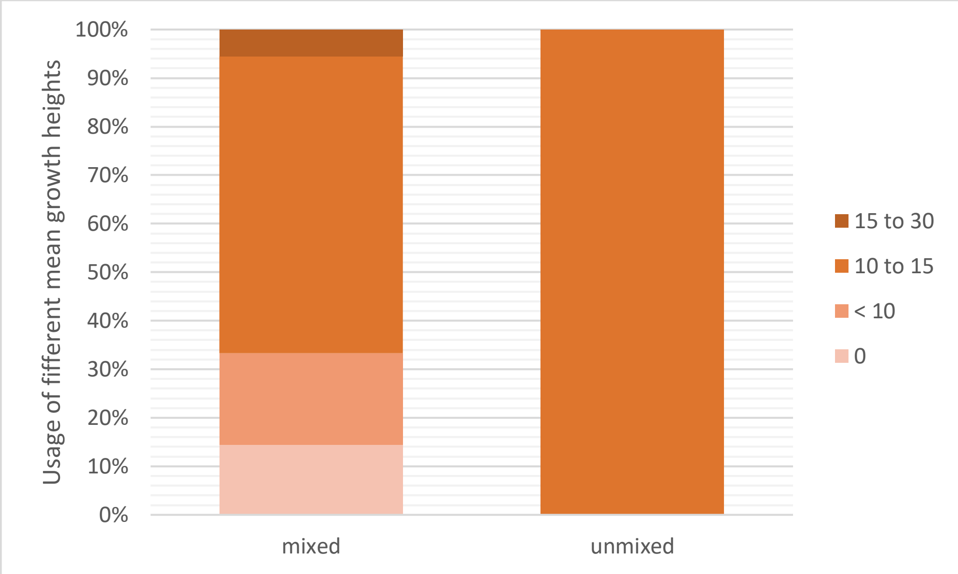

Figure 8. *Percent stacked bar plots of the usage of the different mean growth heights by LWfG. Comparison between mixed and unmixed flocks.*

4. Discussion

4.1 Field choice

This study found a clear preference of the LWfG for specific fields, as specific fields were used more often than expected. Therefore, the second hypothesis of a field preference is confirmed. As predicted, these fields had several analogies. First of all, the fields preferred during the field observations all had a maximum growth height of 15 cm, which gives the LWfG the opportunity to easily overlook the vegetation. This is important for their safety as they need to look out for predators or potential dangers. The fact that vegetation that did not allow all-round visibility reduced the field use was also found in Brent geese (*Branta Bernicla*), a goose species similar sized as the LWfG (Cornell Lab of Ornithology, 2019; Summers & Critchley, 1990). Furthermore, there is evidence that LWfG not only prefer fields with vegetation whose growth height allows the LWfG to look out, but also large fields that allow the geese a view far away (Bogyó & Tar, 2017; Markkola et al., 2003; Tar, 2003).

Other studies also found the LWfG feeding on short grasses (Cong et al., 2012; Tar, 2003). More specifically, they found them feeding on swards smaller than 6 cm. It is likely that they feed on such short swards as the LWfG has a short bill and these swards fit their bite size (Durant et al., 2004). In addition, freshly grown and therefore short swards constitute high quality food as they provide more nutrients (Heuermann et al., 2011; Summers & Critchley, 1990). Moreover, longer swards lead to an increased searching time due to difficulties in locating bites and handling these long swards (Heuermann et al., 2011). From this point of view the preference for fields with a vegetation height up to 15 cm seems rather unlikely, especially in the unmixed flocks as the behavioural observations indicated a priority for feeding effectively. A possible explanation would be that the LWfG feed on smaller swards within the higher vegetation, but this would have to be investigated in another study. This would also allow them to feed in a different microhabitat when feeding with other goose species, especially GG, as they feed on larger swards (Cong et al., 2012; Durant et al., 2004). Fields of this study that were shorter than 10 cm in their mean growth height were mainly pasture areas and therefore had the lower height due to large herbivores grazing. This leaves the remaining vegetation nutrients lower than freshly growing swards, since the nutrient productivity in plants decreases with increasing phytomass and the grass that was grazed on already had a certain phytomass (Kerkhoff & Enquist, 2006).

This study did not investigate the actual diet of the LWfG in this area, which would be beneficial to clarify the reasons behind the field choice. A good and common way to investigate the diet is the analyses of faeces as it was done for example by Cong et al. (2012) in China or by Karmiris et al. (2014) in Greece. Further studies could collect data on the plant composition on the fields and combine it with faeces analyses to get a detailed insight into the field choice based on the vegetation of the LWfG in the area around Hudiksvall.

Another characteristic all preferred fields had in common was their location next to roads and trees. This seems to be rather unlikely a factor to have a positive influence on the field choice as both roads and trees pose potential threats and disturbances. Roads bring human disturbances, as cars are driving by or pedestrians pass. It has been reported for several goose species that human disturbances are disadvantageous, as disturbances lead to flight behaviour. Flight behaviour comes with energetic costs and also performing flight behaviour is at the expense of feeding (Bélanger & Bédard, 1990; Korschgen & Dahlgren, 1992; Owens, 1977).

For the LWfG especially at staging and wintering sites human disturbances are considered a significant threat, which makes it implausible that the LWfG prefer those fields because of their location next to roads (Jones, 2008). Rather is this a hardly avoidable field characteristic of this study, since around 64 % of the fields were neighboured by a road. However, most of the roads were not highly frequented. The influence of the roads is something that should be taken into account for further studies, as it had been shown that roads have an influence on birds' presence depending on the traffic density (Forman et al., 2002).

Trees on the other hand pose the threat of predation as some of the predators of the LWfG, e.g. the White-tailed Eagle (*Haliaeetus albicilla*) and the Goshawk (*Accipiter gentilis*), use trees as hunting perches (Jones, 2008; Kenward, 1982; Nadjafzadeh et al., 2016). Further studies should take the distance of the flock to the trees into account to see if there is an effect. Another possible influence could be the flock composition as all of the by the LWfG preferred fields were used by them in mixed flocks only. Through the benefit from a mixed and hence larger flock, the risk of predation is probably already quite low for the LWfG. This might be enough for the LWfG to do a trade-off and use the fields despite the potential risk of predation indicated by the trees if other characteristics of the field are preferable.

The most prominent similarity of the preferred fields is their location around the same lake with a maximum distance of 500 m to it. The proximity to the lake seems to be a suitable factor influencing the field choice of LWfG as they use open water as roosting place and feed on plants that grow in close proximity to water (Bogyó & Tar, 2017; Cong et al., 2012; Karmiris et al., 2014; Tar, 2003). Furthermore, open water is used by geese to flee from aerial predators, as well as from humans and dogs (Randler, 2003; Schmitt, 1990). If the proximity to the lake indeed is decisive for the field choice, there must be a reason why not all of the fields around the lake were preferred by the LWfG. For four out of eight fields there are possible explanations, as three of them lay next to houses and farms and therefore increased human disturbances are to be expected. In addition, one of these fields has a growth height higher than 15 cm as well as one other field. For the remaining fields, no explanation can without additional research be delivered.

According to the map of citizen observations in the area of Hudiksvall that is provided by the Swedish Redlist, most observations performed by citizens also happened in this area (Artdatabanken, 2020b).

This supports the positive influence of close proximity to open water on the field choice. The GPS data however did not show it that clearly, as not all of the preferred fields of each year laid in this area. Nevertheless, in each year at least one of the preferred fields was in the area around this lake (Fig. A1-A7 in the appendix). The other preferred fields did not lay in such close proximity to water.

As a consequence, the proximity to the lake seems not to be solely decisive for the field choice. Rather was the field choice determined by different factors interacting with each other. This would also explain the small overlap of field preference within the years: The preferred fields change throughout the years because of the change in vegetation and growth height, but the areas in which the preferred fields are located stay the same.

Indicated by the findings of the flock composition, another factor influencing the field choice could be the presence of other goose species. All of the observed species prefered to some extant the same fields, but throughout all years 40 to 100 % of the fields the LWfG preferred were also preferred by GG. This is the highest overlap within the four species. Conversely, GG's preferred fields overlap only up to 46 % with the LWfG's preferred fields. There are two explanations for these findings: Either the requirements the LWfG have towards a field are the same as for the GG or the LWfG orientate on the GG when choosing a field. A combination of both explanations is also possible, as they do not exclude each other. The latter would indicate a priority towards the presence of GG over the field that fits their needs best.

One could also argue that the overlap with the GG is that high due to the high numbers of GG present in the study area, resulting in a high probability to use the same field as them. But this would also mean a large overlap in the preferred fields with the GG for the other study species, especially since the other species are present in higher numbers than the LWfG, resulting in an even higher probability to mix with GG. Since the overlap in the preferred fields of the other two species is smaller than the one between LWfG and GG, this argument seems to not be suitable. Furthermore, it is interesting that the overlap of the preferred fields between the LWfG and the GG is constantly high throughout the years, despite that the fields that were preferred changed. The possibility of the presence of other species influencing the field choice of LWfG is supported by the finding that the LWfG used different agricultural use forms when they were mixed.

On the other hand, GG use the same habitat type as LWfG since they as well prefer a close proximity to water, open country and grassland (Nilsson & Persson, 1992). An important information missing to answer the question of the influence of the presence of GG on the field choice of LWfG is information on the flock composition on these fields during the other years.

This study only gives information about this for the field observations in 2021, but it would be very interesting to have information about it for several years. Therefore, further studies should investigate the influence of the presence of GG on the field choice of LWfG. One way to gain information about that would be to manipulate fields by putting up GG dummies on suitable and rather unsuitable fields and observe the response in field choice by LWfG, similar to the study by Drent and Swierstra (1977).

Furthermore, it cannot be ruled out that there may have been other fields that were used by the LWfG, which were not included into the study fields. One observation of LWfG on the third day of data collection contained 42 individuals, therefore it is known that at least 42 LWfG were present in Hudiksvall during the following days of data collection. However, on ten days the total number of LWfG observed throughout one day did not add up to 42 individuals. If there had been other fields used by the LWfG, nothing is known about these fields regarding their characteristics or location, nor about the behaviour or flock composition of LWfG on these fields. This gap of knowledge could not even be filled with the data gained through the GPS trackers, as in 2021 data were obtained only by one individual.

4.2 Flock composition

The fact that the LWfG were seen in 97 % of the observations in mixed flocks leads to the assumption that the urge to build mixed flocks is greater than the urge to be unmixed and have a field on their own. In this study, the LWfG were found unmixed rather when they were high in numbers of individuals, whereas in mixed flocks rather low numbers of LWfG occurred. Forming an interspecific flock led to a larger flock size. This meets the prediction of mixing with other species to gain a larger flock size and therefore benefit from the dilution effect. The dilution effect lowers the individual risk of predation, as a predator only takes one individual as prey. Therefore, the more individuals there are, the lower is the probability for each individual to be the prey (Kappeler, 2012). However, the largest number of LWfG was observed in a mixed flock. That could be due to a smaller number of individuals joining the other species to a mixed flock and then being joined by more and more other LWfG. Geese tend to land on fields already occupied by conspecifics, since this indicates food of good quality (Drent & Swierstra, 1977).

The LWfG also seem to use the benefit of shared alertness in larger and therefore mixed flocks as they show, as predicted, less alert behaviour when they are in mixed flocks compared to unmixed flocks. Since the results on unmixed flocks are based on only three observations, this might be just a coincidence, with more behavioural observations being necessary. Therefore, for further studies it would be advisable to observe the LWfG the whole time period they spend in Hudiksvall (August and September) (BirdLife International, 2022). There is also a shift in the other behaviours between mixed and unmixed flocks. This is probably due to the benefit of shared alertness giving each individual more time to spent with other behaviours than being alert. The results indicate that, as the majority of an unmixed flock is feeding while approximately 17 % of it are in alert behaviour, the priority in an unmixed flock is to safely feed. This way just the basic need of feeding is covered. In a mixed flock however, more individuals of LWfG are resting and preening than being alert. This way individuals get to cover other important needs that are beneficial for their fitness (Kappeler, 2012). For further studies it would be interesting to investigate if these behavioural changes apply to all species that are part of the mixed flock as Jonsson and Afton (2009) found behavioural differences in two species of a mixed flock.

Possible interspecific competitions that might occur due to feeding in a mixed flock could be avoided through the usage of different microhabitats within the field, as Zhao et al. (2015) as well as Cong et al. (2012) suggested in similar studies. These findings confirm the hypothesis, that the LWfG form interspecific flocks to reduce their risk of predation. Furthermore, the largest mixed flocks containing LWfG were observed on fields next to trees and barns and therefore pose a threat of predation by perch-hunters (Jones, 2008; Kenward, 1982; Nadjafzadeh et al., 2016). This is supported by a field study on tits by Székely et al. (1989) that found tits forming larger interspecific flocks in the presence of predators. In addition, Harrison and Whitehouse (2011) state that especially terrestrial birds of open habitats form mixed flocks, as they are vulnerable to predators. This supports the findings of this study as LWfG have several predators present in Hudiksvall and were less alert in mixed flocks (Jones, 2008).

The prediction, that the LWfG would show less alert behaviour in correlation with an increase in flock size was not met as the proportion of LWfG showing alert behaviour was mainly zero, regardless of the flock size. Furthermore, proportions of LWfG between approximately 25-60 % showing alert behaviour occurred in flock sizes from 1 to 100. The finding of 0 % of LWfG showing alert behaviour in the majority of observations is rather unexpected. Since the alert behaviour was calculated per species and the median of individuals of LWfG had been five, even one individual in alert behaviour would have resulted in 20 % of the LWfG showing alert behaviour. This finding could be due to the way the data were collected: Since the scan samples were done by only one observer it sometimes took a few seconds to scan all of the individuals due to them being scattered among the individuals of the other species. These seconds could have been enough time for them to change their behaviour in the way that the few geese that might have been showing alert behaviour were missed. However, this is normal for the method of scan sampling and the best that can be done is to define behavioural categories that can easily be distinguished as it was done in this study (Altmann, 1974). Another explanation could be that LWfG in mixed flocks rely on the vigilance of the other species they are mixed with, as it was the case for Greenland White-fronted Geese (*Anser* *albifrons flavirostris*) in mixed flocks with GG (Kristiansen et al., 2000). Further studies could also analyse the dominance relationships in mixed flocks containing LWfG as Jonsson and Afton (2009) found the socially dominant species in a mixed flock being less alert as the species they are dominant over.

Furthermore, the results deliver first indications that the field choice is different in mixed LWfG flocks compared to unmixed LWfG flocks with unmixed flocks being only observed on pasture area whereas mixed flocks are also seen on agricultural land such as stubble fields. Thereby, pasture area is not even the most used category of mixed flocks, but the second least. Since this is based solely on three observations, further data are necessary to make safe assumptions. However, this is something that was also observed by Tar (2003) in the Hortobágy area, a main staging site of the LWfG in Hungary, as LWfG only in mixed flocks used agricultural land. As this might bring the LWfG into the risk of being shot or poisoned, Tar (2003) suggests to sow corn for geese. Observations of this study found LWfG feeding on harrowed fields which had fresh sewed corn and later on seedlings on them. With this knowledge it appears to be practical to provide some extra corn. But rather than that, an agriculture that respect the needs of the LWfG in terms of mowing seems to be more of a long-term solution. As Markkola et al. (2003) state, mowing and even better grazing improve the conditions for plants preferred by the LWfG.

Therefore, it might be favourable to identify best suited fields for the LWfG regarding the geographical location. This could be achieved by analyses of long-term data on the field choice in this area combined with information on the agricultural use of the fields in each year to eliminate influences of the vegetation. Those specific fields could then be farmed in favour of the LWfG regarding the vegetation. Therefore, the continued collection of GPS-data to obtain long-term data is necessary. Long-term data are crucial to conservation as they deliver solid information to support single observations quantitatively, furthermore they are able to help evaluating disturbances such as climate change (Holland et al., 2012; Lindenmayer & Likens, 2009).

For further studies it would be interesting to investigate the behaviour of LWfG in mixed and unmixed flocks at other sites in different countries, as the results of this study might only be applicable to this subpopulation of LWfG.

5. Conclusion

To conclude, this study successfully detected a preference for specific fields. Thereby, several parameters might influence the field choice. Besides the flock composition, a mean growth height below 15 cm as well as the vicinity to open water seem to be important for the field choice of the LWfG. The consistently high overlap of the preferred fields between the LWfG and the GG over six years despite the changes in the fields preferred throughout the years further supports the indication of a positive influence of mixed flocks on the field choice of the LWfG. However, this study fails to further investigate this as no data is available concerning both species using the overlapped preferred fields as a mixed flock or at different times in unmixed flocks.

Further research on this influence, e.g. with fields manipulated with GG dummies, would be interesting. This could on the one hand deliver further information on mixed flocks of LWfG and GG, while it could assist the prevention of hunting accidents on LWfG. On the other hand, detailed knowledge on the factors influencing the field choice could help detecting the most suitable fields for LWfG. These could then be farmed in favour of the LWfG and this way prevent the LWfG from going on agricultural fields. On these they might be displaced by farmers or even hunted, since GG often use agricultural fields as well. Furthermore, analyses of LWfG droppings would be favourable to investigate their diet in the study area.

Moreover, this study provides indications that the LWfG might form interspecific flocks to lower their individual risk of predation. This is indicated by a behavioural change in mixed flocks compared with unmixed flocks. Thereby, the behaviour in unmixed flocks consists mainly of feeding and being alert, whereas in mixed flocks the behaviour is more divers. Furthermore, it seems like mixed flocks are rather formed when the LWfG is low in the number of individuals. In addition, this study delivered first evidence that the field choice might also be influenced by the flock composition.

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8. Appendix

8.1 Zusmmenfassung

Beim Erhalten von Tierarten ist Wissen über den Lebensraum der Art wichtig, da er alle Lebensgrundlagen bietet. Genauso wichtig ist es, das Verhalten, sowie dessen Zusammenhang mit der Fitness der Art zu kennen. Ziel dieser Studie ist es, Erkenntnisse über das Habitat der weltweit gefährdeten Zwerggans (*Anser erythropus*, hiernach LWfG) zu gewinnen, sowie über die Faktoren, die die Bildung interspezifischer Scharen beeinflussen. Dazu wurden 102 Felder an einem Zwischenrastgebiet in Hudiksvall, Schweden, beobachtet und hinsichtlich ihrer Eigenschaften kategorisiert. Außerdem wurde die Feldnutzung, in Verbindung mit GPS-Daten aus den Jahren 2014 bis 2020, untersucht. Zusätzlich wurden Daten zur Scharzusammensetzung zwischen LWfG, Graugänsen (*Anser anser*), Kanadagänsen (*Branta canadensis*) und Nonnengänsen (*Branta leucopsis*) zusammen mit dem Verhalten gesammelt. Diese Studie konnte für jedes Jahr bestimmte Feder bestimmen, die von den LWfG bevorzugt wurden. Diese waren nicht über mehrere Jahre konstant. Als mögliche Einflussfaktoren auf die Feldwahl der LWfG in diesem Gebiet wurden in dieser Studie eine Vegetationshöhe von maximal 15 cm, sowie die Nähe zu offenen Gewässern festgestellt. Darüber hinaus konnten auch Hinweise auf einen Einfluss der Scharzusammensetzung auf die Feldwahl gefunden werden. Da LWfG in gemischten Scharen weniger wachsames Verhalten zeigten, deutete das auf eine Bildung interspezifischer Scharen zur Verringerung des Prädationsrisikos hin. Die gefundenen Informationen zur Habitatwahl sowie zu den interspezifischen Beziehungen können Schutzprogrammen helfen, wichtige Lebensräume für die LWfG zu schützen.

Table A1. *Ethogram (after Boz et al. (2021), Drent and Swierstra (1977), and Fox and Madsen (1981))*

Behaviour	Definition
Resting	The goose is sitting or standing without showing any of the other behaviours. The eyes can be closed and the head can be rested on the back.
Feeding	The goose performs any type of feeding: grazing, drinking, picking seeds from the ground.
Preening	The goose is manipulating its own feathers, including pauses between each bill-feather contact.
Alert	The goose is in an alert position: Head up, neck stretched, eyes open.

Table A2*. Table of the field choice of LWfG for X^2 Test (X^2 = 84.323, $X^2_{(0.05)}$ = 33.92 / $X^2_{(0.005)}$ = 42.80, df = 22). Red lines marking border between fields with fo > fe, fo = fe and fo < fe.*

field_ID	observed frequency (fo)	expected frequency (fe)	(fo - fe)	$(fo - fe)^2$ / fe
field_75	17	4.043	12.957	41.517
field_100	12	4.043	7.957	15.656
field_30	8	4.043	3.957	3.871
field_93	8	4.043	3.957	3.871
field_72	5	4.043	0.957	0.226
field_83	5	4.043	0.957	0.226
field_31	4	4.043	-0.043	0.000
field_43	4	4.043	-0.043	0.000
field_64	4	4.043	-0.043	0.000
field_102	3	4.043	-1.043	0.269
field_48	3	4.043	-1.043	0.269
field_69	3	4.043	-1.043	0.269
field_74	3	4.043	-1.043	0.269
field_41	2	4.043	-2.043	1.033
field_44	2	4.043	-2.043	1.033
field_90	2	4.043	-2.043	1.033
field_92	2	4.043	-2.043	1.033
field_101	1	4.043	-3.043	2.291
field_36	1	4.043	-3.043	2.291
field_40	1	4.043	-3.043	2.291
field_49	1	4.043	-3.043	2.291
field_91	1	4.043	-3.043	2.291
field_99	1	4.043	-3.043	2.291
total	**93**	**93.000**		**84.323**

Table A3. *Table of the field choice of Barnacle Geese for X^2 Test (X^2 = 111.297, $X^2_{(0.05)}$ = 42.65 / $X^2_{(0.005)}$ = 52.34, df = 29). Red lines marking border between fields with fo > fe, fo = fe and fo < fe.*

field_ID	observed frequency (fo)	expected frequency (fe)	(fo - fe)	$(fo - fe)^2$ / fe
fiel_76	21	7.067	13.933	27.472
field_93	19	7.067	11.933	20.152
field_48	18	7.067	10.933	16.916
field_75	18	7.067	10.933	16.916
field_43	15	7.067	7.933	8.906
field_6	13	7.067	5.933	4.982
field_30	10	7.067	2.933	1.218
field_36	9	7.067	1.933	0.529
field_35	8	7.067	0.933	0.123
field_47	8	7.067	0.933	0.123
field_40	7	7.067	-0.067	0.001
field_42	7	7.067	-0.067	0.001
field_49	7	7.067	-0.067	0.001
field_7	7	7.067	-0.067	0.001
field_100	6	7.067	-1.067	0.161
field_41	5	7.067	-2.067	0.604
field_72	5	7.067	-2.067	0.604
field_74	5	7.067	-2.067	0.604
field_102	4	7.067	-3.067	1.331
field_44	3	7.067	-4.067	2.340
field_83	3	7.067	-4.067	2.340
field_84	3	7.067	-4.067	2.340
field_31	2	7.067	-5.067	3.633
field_69	2	7.067	-5.067	3.633
field_92	2	7.067	-5.067	3.633
field_34	1	7.067	-6.067	5.208
field_5	1	7.067	-6.067	5.208
field_80	1	7.067	-6.067	5.208
field_98	1	7.067	-6.067	5.208
field_99	1	7.067	-6.067	5.208
total	**212**	**212.000**		**111.297**

Table A4. *Table of the field choice of Canada Geese for X^2 Test (X^2 = 176.568, $X^2_{(0.05)}$ = 48.60 / $X^2_{(0.005)}$ = 58.96, df = 34). Red lines marking border between fields with fo > fe, fo = fe and fo < fe.*

field_ID	observed frequency (fo)	expected frequency (fe)	(fo - fe)	$(fo - fe)^2$ / fe
field_75	23	6.943	16.057	37.136
field_6	22	6.943	15.057	32.655
field_43	21	6.943	14.057	28.461
field_34	20	6.943	13.057	24.556
field_72	13	6.943	6.057	5.284
field_48	10	6.943	3.057	1.346
field_93	9	6.943	2.057	0.610
field_102	8	6.943	1.057	0.161
field_30	8	6.943	1.057	0.161
field_74	8	6.943	1.057	0.161
field_100	7	6.943	0.057	0.000
field_35	7	6.943	0.057	0.000
field_36	7	6.943	0.057	0.000
field_5	7	6.943	0.057	0.000
field_64	7	6.943	0.057	0.000
field_83	7	6.943	0.057	0.000
field_84	6	6.943	-0.943	0.128
field_31	5	6.943	-1.943	0.544
field_91	5	6.943	-1.943	0.544
field_99	5	6.943	-1.943	0.544
field_47	4	6.943	-2.943	1.247
field_49	4	6.943	-2.943	1.247
field_69	4	6.943	-2.943	1.247
field_101	3	6.943	-3.943	2.239
field_41	3	6.943	-3.943	2.239
field_44	3	6.943	-3.943	2.239
field_76	3	6.943	-3.943	2.239
field_92	3	6.943	-3.943	2.239
field_40	2	6.943	-4.943	3.519
field_42	2	6.943	-4.943	3.519
field_58	2	6.943	-4.943	3.519
field_7	2	6.943	-4.943	3.519
field_70	1	6.943	-5.943	5.087
field_73	1	6.943	-5.943	5.087
field_78	1	6.943	-5.943	5.087
total	**243**	**243.000**		**176.568**

Table A5. *Table of the field choice of Greylag Geese for X^2 Test (X^2 = 225.233, $X^2_{(0.05)}$ = 46.19 / $X^2_{(0.005)}$ = 56.33, df = 32). Red lines marking border between fields with fo > fe, fo = fe and fo < fe.*

field_ID	observed frequency (fo)	expected frequency (fe)	(fo - fe)	$(fo - fe)^2$ / fe
field_93	34	8.212	25.788	80.980
field_75	24	8.212	15.788	30.352
field_100	22	8.212	13.788	23.149
field_30	22	8.212	13.788	23.149
field_72	19	8.212	10.788	14.172
field_31	17	8.212	8.788	9.404
field_83	16	8.212	7.788	7.386
field_6	14	8.212	5.788	4.079
field_92	12	8.212	3.788	1.747
field_74	11	8.212	2.788	0.946
field_99	11	8.212	2.788	0.946
field_69	10	8.212	1.788	0.389
field_34	9	8.212	0.788	0.076
field_102	7	8.212	-1.212	0.179
field_64	7	8.212	-1.212	0.179
field_94	4	8.212	-4.212	2.160
field_101	3	8.212	-5.212	3.308
field_73	3	8.212	-5.212	3.308
field_76	3	8.212	-5.212	3.308
field_84	3	8.212	-5.212	3.308
field_90	3	8.212	-5.212	3.308
field_44	2	8.212	-6.212	4.699
field_80	2	8.212	-6.212	4.699
field_91	2	8.212	-6.212	4.699
field_95	2	8.212	-6.212	4.699
field_97	2	8.212	-6.212	4.699
field_35	1	8.212	-7.212	6.334
field_43	1	8.212	-7.212	6.334
field_7	1	8.212	-7.212	6.334
field_70	1	8.212	-7.212	6.334
field_78	1	8.212	-7.212	6.334
field_86	1	8.212	-7.212	6.334
field_98	1	8.212	-7.212	6.334
total	**271**	**271.000**		**225.233**

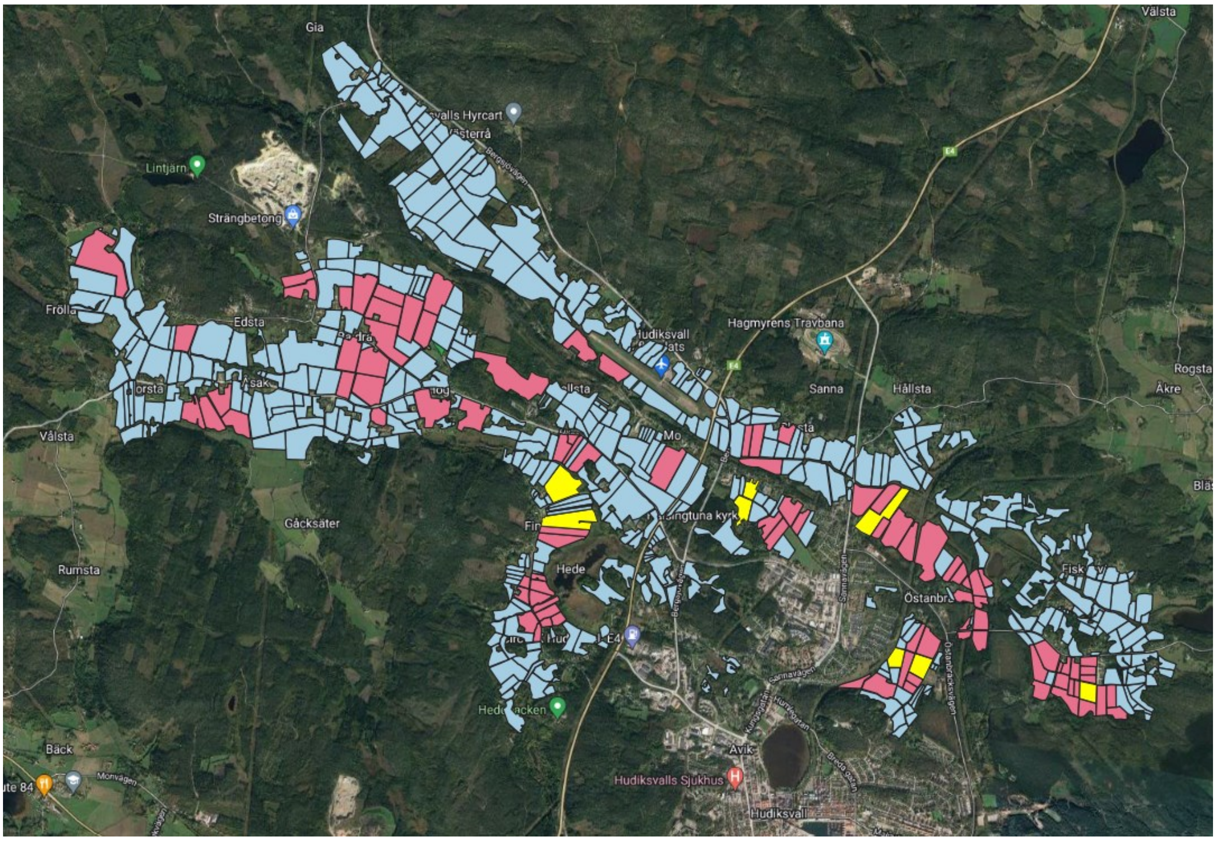

Figure A1. *Map of the fields preferred by the LWfG in 2015 (highlighted in yellow) withing the study fields (red) and the due to the GPS data added fields (blue). Based on the GPS data.*

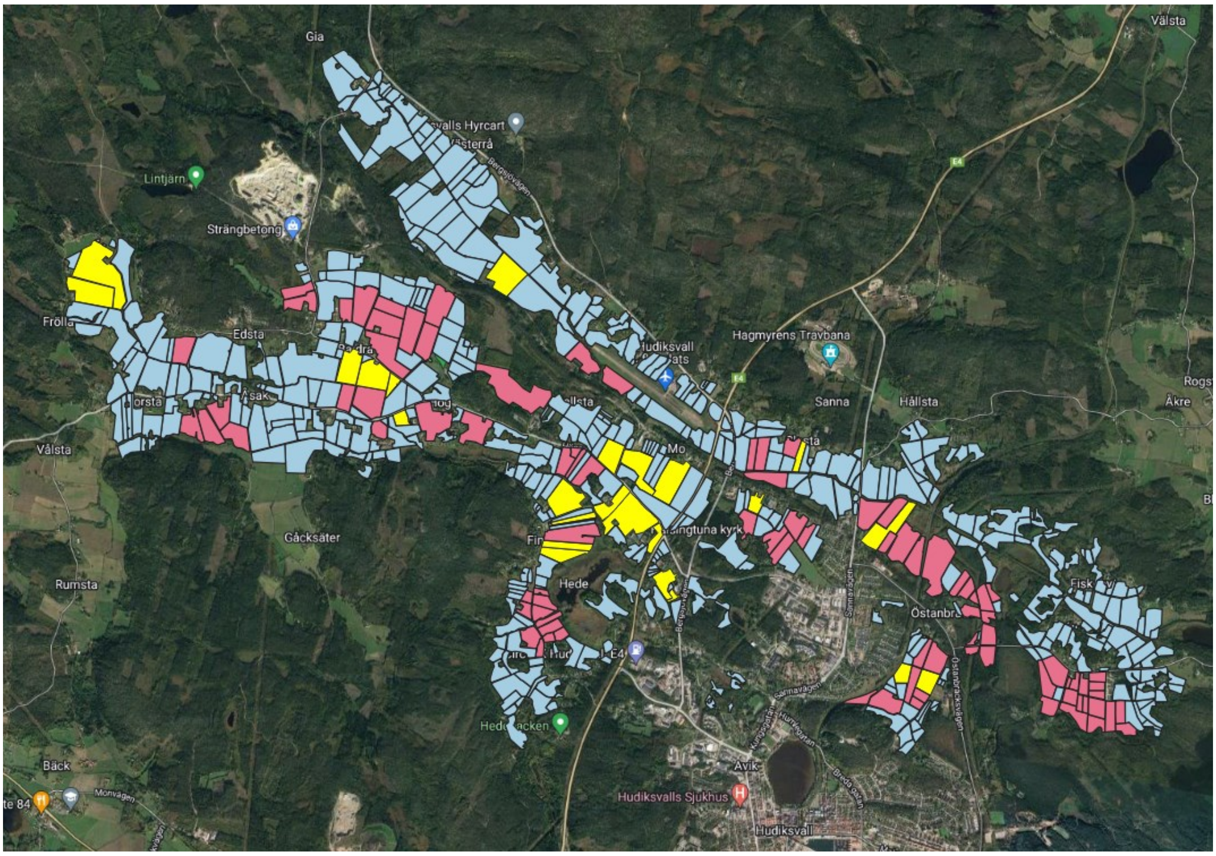

Figure A2. *Map of the fields preferred by the LWfG in 2016 (highlighted in yellow) withing the study fields (red) and the due to the GPS data added fields (blue). Based on the GPS data.*

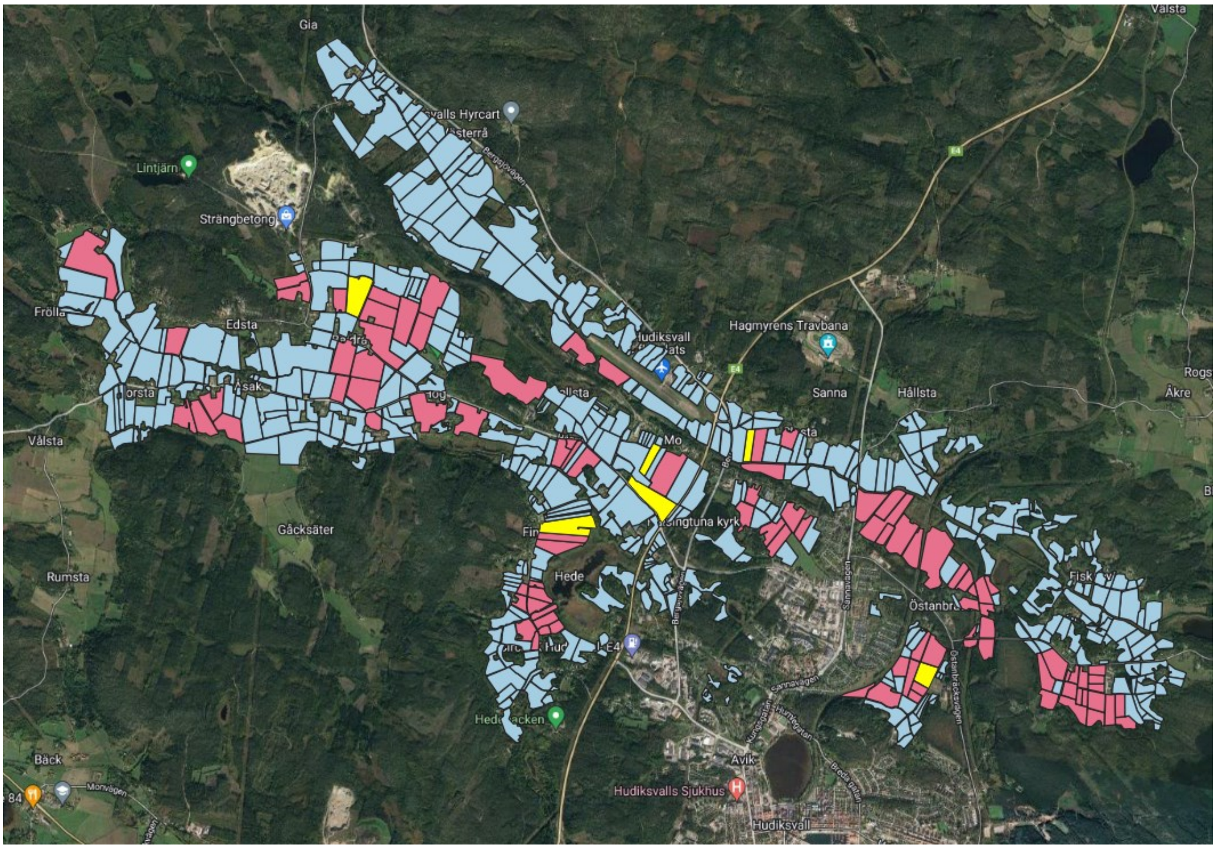

Figure A3. *Map of the fields preferred by the LWfG in 2017 (highlighted in yellow) withing the study fields (red) and the due to the GPS data added fields (blue). Based on the GPS data.*

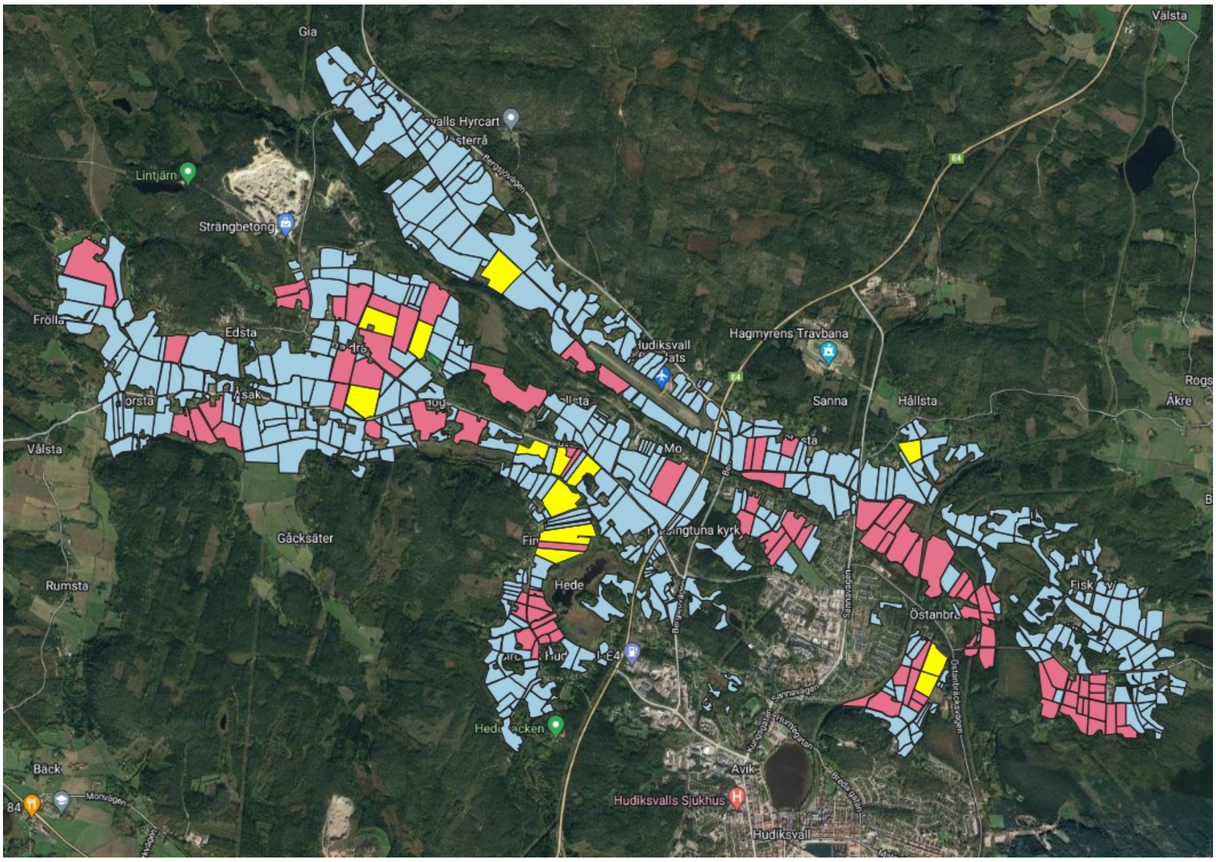

Figure A4. *Map of the fields preferred by the LWfG in 2018 (highlighted in yellow) withing the study fields (red) and the due to the GPS data added fields (blue). Based on the GPS data.*

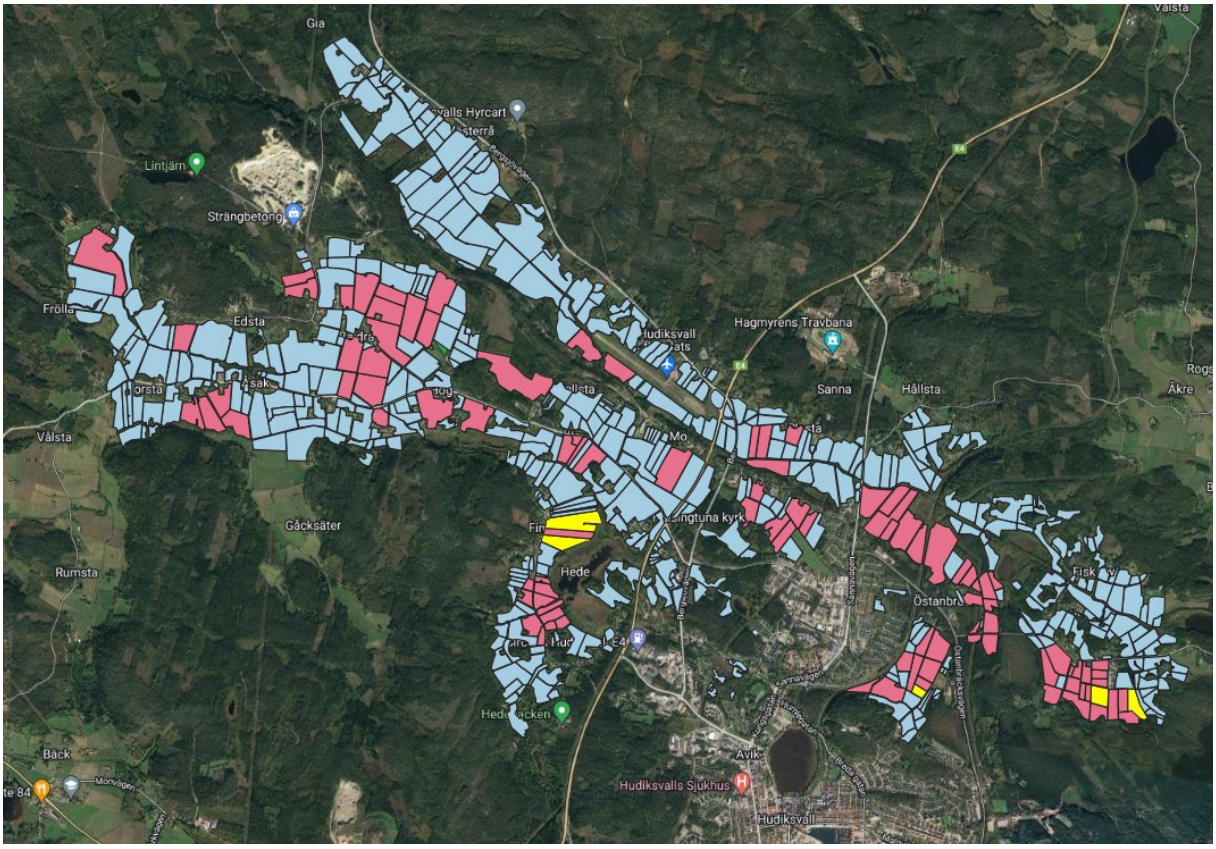

Figure A5. *Map of the fields preferred by the LWfG in 2019 (highlighted in yellow) withing the study fields (red) and the due to the GPS data added fields (blue). Based on the GPS data.*

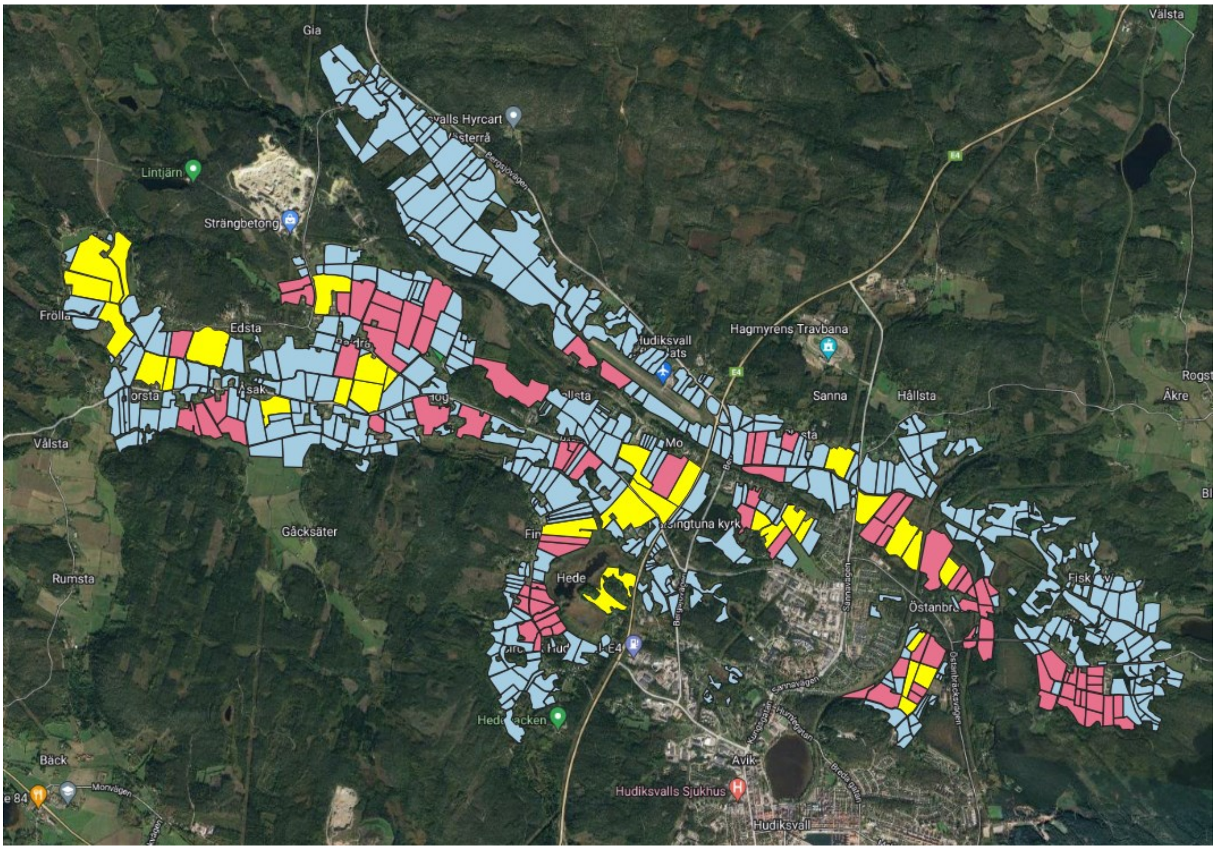

Figure A6. *Map of the fields preferred by the LWfG in 2021 (highlighted in yellow) withing the study fields (red) and the due to the GPS data added fields (blue). Based on the GPS data.*

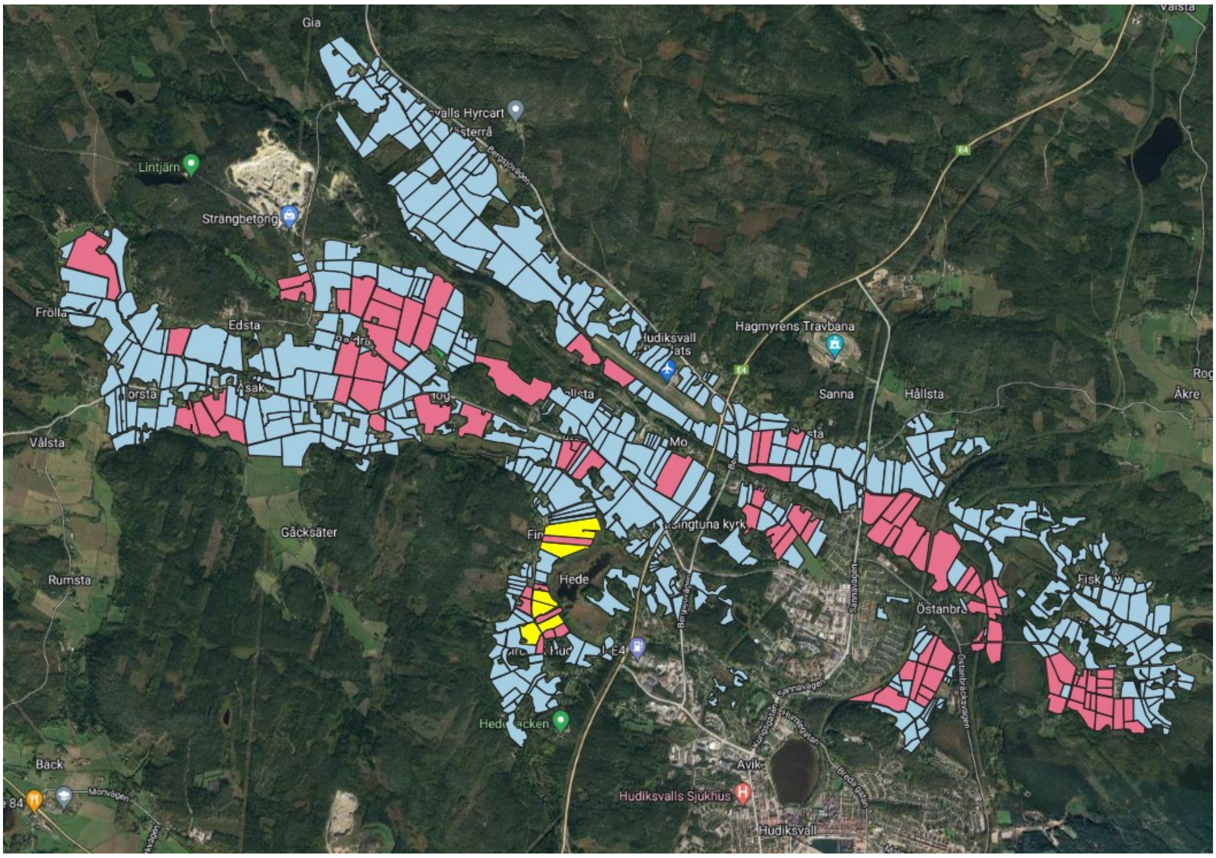

Figure A7. *Map of the fields preferred by the LWfG in 2021 (highlighted in yellow) withing the study fields (red) and the due to the GPS data added fields (blue). Based on the field observations.*